Q&A 10	Schenewerk on laws for a space society
DECARBONIZATION 32	Designing airframes for efficiency
ARTIFICIAL INTELLIGENCE 42	Applying AI wisely for defense

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HYDROGEN

The competing ideas for how to store it aboard passenger aircraft to meet the net-zero challenge PAGE 22

IN-SPACE MANUFACTURING

BRINGING THE PRODUCTS HOME

PAGE 16

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California startup Universal Hydrogen is among the companies designing hydrogen fuel tanks for passenger aircraft. This is a prototype of one of Universal's tank or "capsule" designs for storing gaseous hydrogen during ground transport and aboard an aircraft. The capsules, part of an end-to-end kit for converting today's turboprop planes into hybrid-electric ones, would be constructed of a woven carbon fiber composite, with an internal membrane to keep hydrogen molecules from escaping. Universal Hydrogen

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IN THIS ISSUE

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Moriba is an associate professor at the University of Texas at Austin and chief scientist at Privateer. He helped navigate spacecraft at NASA's Jet Propulsion Lab and researched space situational awareness issues at the U.S. Air Force Research Laboratory.

PAGE 64

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Aaron is a contributing editor to the Aviation Week Network and has covered the aviation business for decades. He was previously managing editor of Air Cargo World and editor-in-chief of Aviation Daily.

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PAGE 22

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PAGE 16

DEPARTMENTS

Speeding up the innovation game

Want to decarbonize air travel by 2050? Bop around town in an electric rotorcraft a few years from now? Watch Americans return to the moon in 2025? Visit a moon base? Deter aggressors with hypersonic weapons or ride on a hypersonic aircraft?

None of these or other aspirations can be achieved in a timely way unless the United States and its friends sharpen their processes. More journalism and academic work needs to be done to find possible solutions to this collective slowing down of our ability to achieve moonshot-scale things.

Complaining is not solving. I've been hearing about our loss of Apollo moxie since I entered science and technology journalism in the early 1990s amid a debate over the kind of spacecraft that should replace the space shuttles. There's still nothing better flying or even on the drawing board.

Most recently, a 2019 column by Victor Davis Hanson resurfaced on LinkedIn with its provocative headline, "Members of previous generations now seem like giants — When did we become so small?" The piece asks: "Does anyone believe that contemporary Americans could build another transcontinental railroad in six years?"

No one could plausibly declare "yes" to that question.

If someone has a solution to the slowing of innovation, they should speak up. Democratic and Republican administrations and Congresses have come and gone since the early 1990s, and none have wowed us like Apollo. We don't have nuclear-powered probes in the Jovian system, hypersonic missiles deterring anyone, or Americans back on the moon. Some of these things are coming soon, but I've heard that before.

Here is a notional problem statement: "We must speed up the pace of aerospace innovation without causing environmental, societal or safety outcomes that outweigh the benefits of the innovations."

What I mean is, we must not speed up the game by shredding the wrong regulations or by turning a blind eye to the collateral damage of what we do.

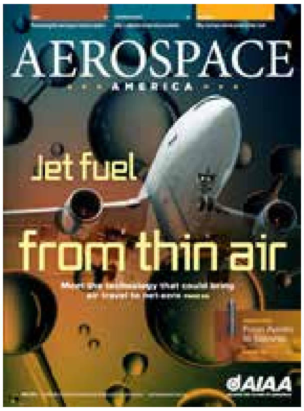
Green, clean electric rotorcraft will be a revolutionary mode of transportation, but we still need FAA to do its part to make them as safe as possible. Someone must decide where they should and shouldn't fly to avoid harming neighborhoods, as happened needlessly with construction of the Interstate Highway network in the United States.

The free world needs better weapons than authoritarian regimes, but we need to develop those without adding more environmental Superfund cleanup sites. Being in a rush can't be a license to pollute.

Balancing these seemingly incompatible priorities is a big ask, but it's one scaled to meet the audacious goals the aerospace community has set for itself. ★

Ben Iannotta, editor-in-chief, beni@aiaa.org

Reactions to "Jet fuel from thin air"



Let us hear from you

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The article was excellent, and it shows that capturing atmospheric carbon dioxide is the key to the future of aviation fuel. In my own experience, though, each chemical step will add an additional cost to the fuel. In electrically synthesized fuel, the cheapest fuel is liquid hydrogen, followed by liquid methane and finally methanol. This, of course, does not include the cost of the hardware to use the fuel. Carbon capture will allow us to use fossil fuels beyond the 2050 net-zero deadline, permitting a slower transition to full sustainability. It is my hope that methane will find a niche as an aviation fuel. It is not perfect, but the question is what is the best choice? I discount biofuels as being too resource intensive. Perhaps I am wrong. There is a growing interest in ammonia as a jet fuel. Is this the best solution? It is time to explore our options.

James H. Sloan, AIAA senior member
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Thanks for the interesting article on carbon neutral fuel in the May issue. Just one issue: There was no mention on where the electricity for electrolysis comes from. The sustainability loop has not been closed.

Rodger Herbst, AIAA member
Snohomish, Washington

Author's response: *Prometheus plans to obtain the electricity for electrolysis from renewable energy sources including solar and wind, so the resulting fuel would be carbon neutral. — Karen Kwon*

FLIGHT PATH

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Laura McGill
AIAA President (2022–2024)

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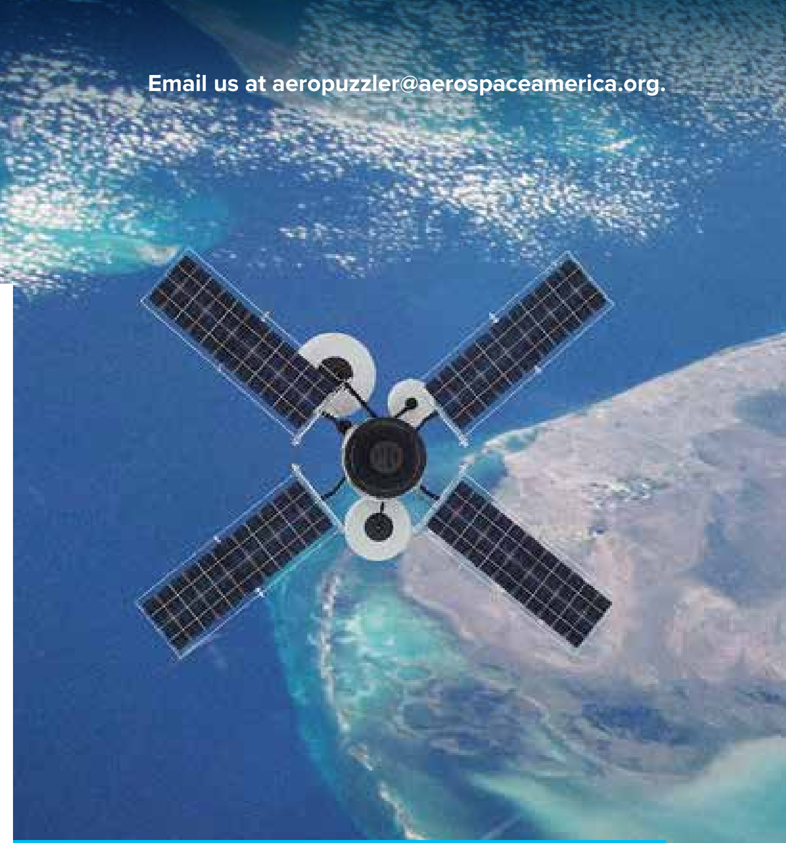

Explaining spin

Q: You are on a television game show, and you are the real engineer while seated next to you is an imposter. Each of you must convince the audience that you are the true professor. The host asks the imposter, a sportswriter who washed out of aerospace engineering after a semester, to explain why some satellites are spin stabilized. The imposter proclaims that “a spin-stabilized satellite follows a smooth orbital path and attitude around Earth, and if it weren’t spun, it would tumble and float confusingly, much like a baseball pitcher’s knuckleball, and for the same reason: a baseball is not perfectly spherical, and this uneven mass makes it tumble.” Now it’s your turn. What would you say?

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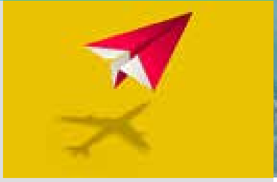
FROM THE JUNE ISSUE

PAPER AIRPLANES VERSUS REAL-LIFE AIRCRAFT:

We asked you to explain why paper airplanes don’t need tails.



WINNER Airplane 101, here we go. The fuselage is the compartment where everyone is seated in a plane. The wings are connected to the sides of the fuselage and are near the middle. The tail is located at the end of the fuselage consisting of two smaller horizontal wings coming out the sides of the body and one vertical wing attached to the top. The tail’s main function is to maintain the stability of the plane. The horizontal stabilizers (rear horizontal wings) keep the plane level or control the “pitch” (up and down motion), and the vertical stabilizer (rear vertical wing) controls the “yaw” (left and right motion). So if the tail is needed for stable flight, why doesn’t a paper airplane need one? Well, a paper airplane has a sneaky way of mimicking a tail while just using its fuselage and wings. Assuming you’ve used a paper airplane, we know that we throw them from the vertical piece sticking out from between the bottom of the wings (fuselage in this case). That is the vertical stabilizer portion of the tail. But what about the horizontal portion? Paper airplane wings are flat, unlike those on real airplanes, which are curved. With flat wings, if you move the center of mass of the paper airplane to an ideal location, you can make the forces on the wing balance out so if the nose (front of the fuselage) points too high or too low it will level back out, creating the perfect glide.

Joshua Hernandez, AIAA student member
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Joshua is a rising junior studying aerospace and mechanical engineering at the University of Buffalo.

Air cruising

BY AARON KARP | aaronkarp74@gmail.com

Imagine clinking champagne glasses aboard a helium airship in the midst of a five-day luxury "air cruise" with daily stops at tourist destinations.

That's the vision of Hybrid Air Vehicles, or HAV, the U.K.-based company that for a decade has been seeking to create and sell aircraft blending the lift of helium with the advantages of the aerodynamic lift of heavier-than-air vehicles.

HAV calls its hybrid design Airlander 10. The company received a major boost in June, when Spanish airline Air Nostrum provisionally ordered 10 of the aircraft to operate on domestic routes. Gaining a launch customer provides HAV the impetus to start production.

HAV aims to gain a U.K. Civil Aviation Authority type certificate for Airlander 10 by 2026 via a three-aircraft test program.

"We like to call it a hybrid aircraft," HAV Chief Operating Officer Nick Allman says. "It is a combination of aerostatic lift from helium, aerodynamic lift from its hull shape and the ability to vector the thrust of engine propellers."

The first Airlander 10s will be propelled by helium and four diesel engines produced by RED Aircraft GMBH of Germany, a maker of diesel piston engines. HAV eventually wants to shift to four electric engines after an interim step of two diesel engines and two electric engines. HAV aims for zero-emissions, electric-powered Airlander 10s to be flying by 2030.

But even with four combustion engines, the aircraft will be much more efficient — if slower — than traditional fixed-wing commercial aircraft, Allman says. The "free lift" provided by helium is the key feature allowing the Airlander 10 to use much less power than traditional airliners.

"The hull of the aircraft floats with no energy," Allman says. "Really, we're only using the engines to give us some forward speed and to lift the payload."

The aircraft will take off and land on any large flat surface — no airport needed. The Airlander will roll to take off as an airplane does but will go aloft when it reaches a speed of about 55 kilometers per hour. In cruise, the 10-metric ton payload aircraft will reach speeds of up to 130 kph. Landing will happen simply by turning off the motors and pumping air into the fuselage.

"If you start off with a latex helium party balloon and you take it up 1,000 feet, it would get bigger because the air pressure around that balloon goes down and the helium therefore is able to expand," Allman explains. "When the Airlander is on the ground, only around half of that fuselage space is full of helium and half of it is actually filled with air. As we go up in altitude, we let air out of that space. As we come down in altitude, we pump air back in."

The Airlander design is an evolution of the Long Endurance Multi-Intelligence Vehicle, a surveillance airship HAV built with Northrop Grumman for the U.S. Army. The service flew the aircraft just once in 2012 before canceling the program because of budget constraints. HAV then began focusing on commercial viability. ★

▲ A hybrid airship prototype combining the lift from helium with aerodynamic lift flies near Cardington Airfield in England. Hybrid Air Vehicles plans to begin passenger services in the mid-2020s with its Airlander 10 vehicles, a design it flew for the first time in 2016.

Hybrid Air Vehicles

Building space societies

When Jeff Bezos inspires us with visions of colonies in low-Earth orbit or Elon Musk tweets about terraforming Mars, the need to discuss the laws that would govern such off-world societies might not spring immediately to mind. But lawyer Caryn Schenewerk believes it's these "unsexy" discussions that will pave the way for humanity to expand beyond Earth. She participates in such discussions in her volunteer role at the Commercial Spaceflight Federation industry group. She views the situation today as similar to about a decade ago, when SpaceX proposed reusing rocket stages and discovered that FAA's licensing rules on the topic were written with suborbital vehicles in mind. Similarly, today's international laws, including the Outer Space Treaty of 1967, are inadequate, she believes. Among the many considerations are how to enforce laws in societies hundreds and thousands of kilometers from Earth and how to resolve disputes between residents hailing from perhaps dozens of different nations. I called Schenewerk to discuss these issues and more. — *Cat Hofacker*

CARYN SCHENEWERK

Positions: Since November, chair of the Commercial Spaceflight Federation executive committee board. Since July 2020, based in Washington, D.C., as vice president of regulatory and government affairs for rocket builder Relativity Space of Long Beach, California. She lobbies Congress for legislation favorable to the company. 2011-2020, senior counsel and senior director of spaceflight policy at SpaceX. 2009-2011, deputy to the associate director for legislative affairs at the Office of Management and Budget. 2007-2009, deputy chief of staff and policy director for U.S. Rep. Gabrielle Giffords, D-Ariz.

Notable: Participated in SpaceX's efforts to gain U.S. congressional approval and funding for the Commercial Crew Program in which NASA partially funded the development of privately owned capsules to carry astronauts to the International Space Station. Also at SpaceX, lobbied for updating FAA licensing to streamline launch and re-entry requirements, including allowing a single operator's license to cover multiple launch vehicles and sites, changes now largely reflected in the revised Part 450 rules released in late 2020.

Age: 45 — her birthday is July 20, so she's a self-proclaimed "moon baby."

Resides: Washington, D.C.

Education: Bachelor of Arts in literature, Austin College in Texas, 1999; juris doctorate, University of Texas School of Law, 2002.

Q: When you hear these grand visions of millions of people living in low-Earth orbit or establishing moon and Mars colonies, where does your mind go?

A: One of the things that's important about those kinds of challenges is taking the time to learn about what we've done in the past in analogous situations and what lessons we can learn from those. Of course, it won't be perfectly informative, but I think about, "What did it look like when we were pioneering the West of the United States or when we were settling other continents?" One big difference for space exploration is that we don't think at this point that there are people indigenous to Mars, but we will have to deal with multiple nations exploring simultaneously and think of what rules of law we will need to apply. The Outer Space Treaty and accompanying documents establish a framework for how we operate in space and on celestial bodies, but there are a lot of interpretations on that. I like to joke sometimes that if you have six lawyers, you can get 12 opinions. Some things are purposely not specifically defined in those treaties so as to be able to flex with the ages, so when multiple nations are exploring the same celestial body, we will have to figure out how those entities interact and what it looks like to set up rules of governance. In the United States, we have a system of laws that's very much tied to states — tort law, for example, is based on what state you're coming from. So for instance, are early explorers going to be more like members of the military? — You're deployed from a home state, so you're subject to and governed by the laws of that state; that's where you vote; that's where you pay taxes. What does that look like in early exploration versus in the distant future? If we have a more developed colony someday, might it have some autonomy and set up its own rules of governance, and then how does that interplay with our 50 states on Earth in our constitutional republic government?

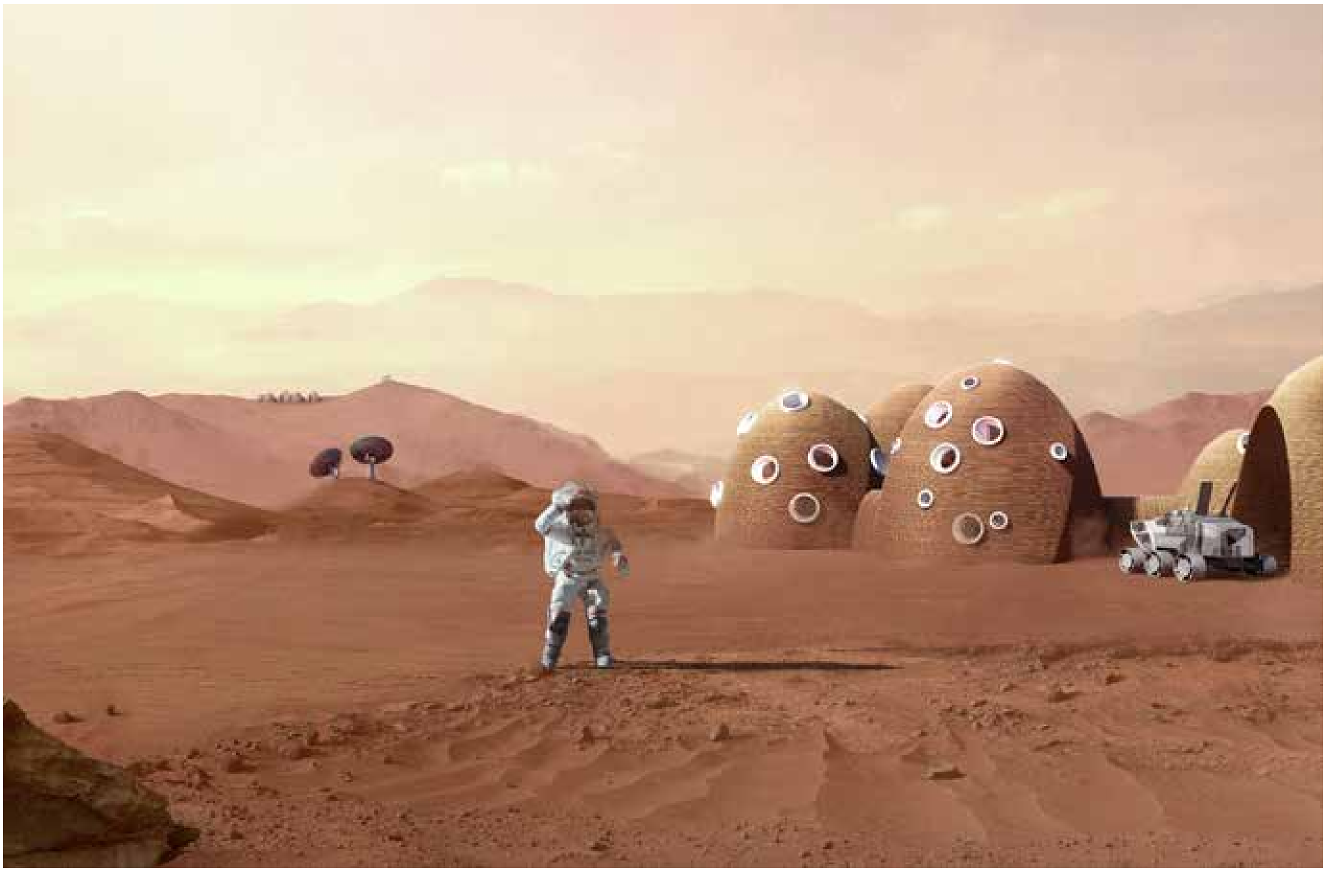
Q: Might this be a scenario where even if it's technologically possible to create an in-space colony, the legal framework has to be in place before it can be established?

A: We're going to need to hit some milestones technologically and exploration-wise before we see significant thought and effort put into what it looks like to have governance of those activities, especially if there are diverse activities across the private and government sectors. People make terrible jokes all the time about bureaucracy, that you start with "no" and then you have to get to "yes." I actually think that the American spirit starts with "yes." So that means that when we start exploring, while we might get ahead of having any kind of specific laws to what people are doing on the books, we will be able to come up with requirements and policies that address that without having to pass statutes and regulations immediately. At the same time, we are working on regulations on Earth that could enable a space settlement. The U.S. Department of Commerce is working on overseeing novel or nontraditional activities; these are the kinds of activities that would fall within that potential future approval process for a space settlement. Then when it comes to governance, I think we'll see that those early space explorers will probably be governed in some form or fashion by what's happening in the U.S., but they're going to be very much governed by their ability to operate and survive in space. Think of the early pioneers; they weren't necessarily a full society. Then as those settlements grow, we're more likely to have the development of those kinds of rules.

"When it comes to governance, I think we'll see that those early space explorers will probably be governed in some form or fashion by what's happening in the U.S."

Q: This reminds of the moon colony in Andy Weir's "Artemis" where the residents retain their Earth citizenship of whatever nation they came from. Is that a realistic starting point for a multination space settlement, or might we someday have an independent moon colony, for instance?

A: I love the idea that anything is possible here, and I would love to think that whatever the governance structure is, it's a result of peaceful decisions and



▲ This illustration of a Mars habitat was among the submissions for NASA's 3D-Printed Habitat Challenge. The multiphase competition required entrants to 3D print structural components for deep space habitats, an essential skill for a future self-sufficient space colony.

Logan Architecture

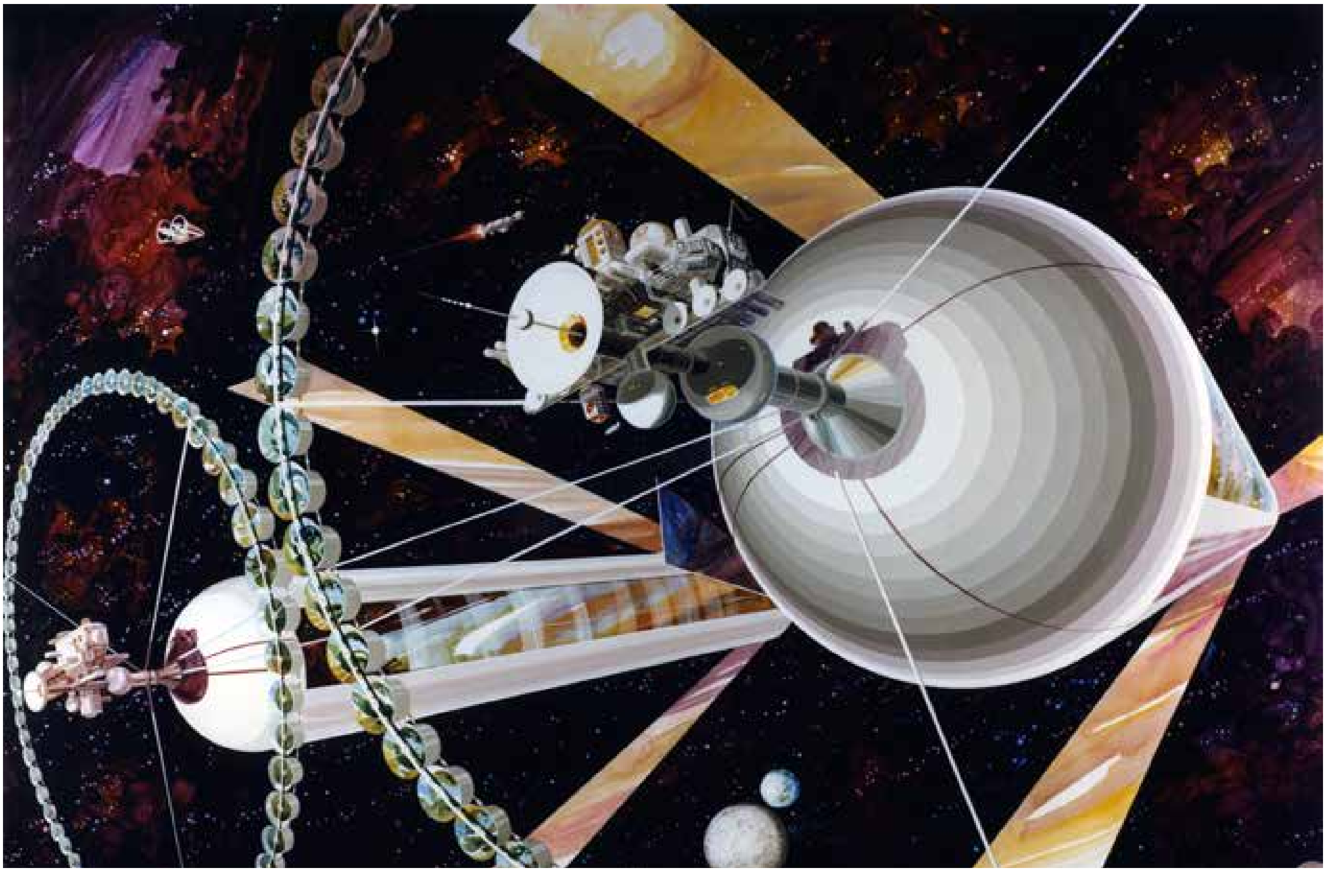
thoughtful people coming together — hopefully in a democratic way — to determine how they want to be governed. The idea that you'll have multiple people coming together from multiple places is absolutely one of the many options for how this could occur, and that you would carry your citizenship with you to this new place. There will be some need for engagement around how they interact with each other and what a system of justice looks like to resolve conflicts between them. Let's just keep it to contractual conflicts — is it an international dispute that needs to be resolved on Earth? Or is it a dispute that we have a means to resolve at the settlement based on some agreed set of principles? My pure guess is that it's an evolution; we're going to start one place and end up somewhere else. Another scenario is that this is an international exploration activity from the start, in which case something like the International Space Station Intergovernmental Agreements that apply to the individuals on the space station and how conflicts are resolved between them could be a good starting point.

Q: As you've said, the Outer Space Treaty provides many basic principles for exploration, but there's disagreement about whether it actually allows for a settlement on another celestial body. Which camp are you in?

A: I am in the camp that I don't think it explicitly prohibits the idea that people would create settlements and undertake exploration in an organized fashion. Maybe a rough comparison is if you pitch a tent on a piece of land, you would then have some expectation of being able to sleep in your tent for some number of days without being disturbed. The OST should be used to influence the idea that we should be collaborating and that we should be communicating and that we should not be declaring exclusive use or ownership versus disallowing, as you said, any kind of settlement or exploration.

Q: That gets tricky very quickly. If everyone has the right to colonize the moon, for instance, does that mean every nation is entitled to the same size piece of land? Is a new treaty required to address questions like that?

A: One can argue that: Are we appropriating orbits, or are we appropriating space on the moon or Mars? Anything in space in theory is subject to the concept of equal ownership in this framework, but by virtue of physics, we can't all be in the same place at exactly the same time. We're going to have to, in some way, divide access or grant access and address this concern, but I don't necessarily see us coming internationally together to change or develop a whole new Outer Space Treaty. I think we are more likely to see



interpretations of the treaty through things like NASA's Artemis Accords, agreements that started off bilateral and then built out to be multilateral. The ISS IGA [Intergovernmental Agreement] is another example of where some number of countries that developed the technical ability to pursue an exploration objective came together and came to some form of agreement about how that space hardware would be used. On Earth, we also have things like codes of conduct and sustainability guidelines, so we've come together to answer the same questions in other aspects and behaviors with regard to hardware in space and private interests. That will provide some precedent for whatever kind of question you're asking, whether it's about undertaking science or harvesting rare earth metals. It could even be something intangible like the position of some piece of hardware with regard to the sun, and therefore the best place to gather solar energy to power other activities in space. Also, increasing technological capabilities ahead of us will make some of these questions a little bit different — and in some cases easier to answer, in some cases harder to answer. For example, with additive manufacturing, do we need to set up a huge manufacturing plant on the moon or Mars that would take up a lot of space and take up a lot of energy and effort to transport goods there and fix tooling? Or could we put something like a robotic arm with the materials it needs to print in this location and then over there in that location? That would spread it out in ways that it benefits various entities that need access to it but also has a much smaller footprint than a huge manufacturing facility.

Q: Shifting gears a bit: there's governance and then there's enforcement. Let's say labor laws on the moon allow for 10-hour shifts because of the lack of gravity, but Company X works their employees 14 hours and has no incentive to stop because the United Nations committee or whoever enforces those laws is all the way back on Earth. So how do we not create a space society where some people have more rights than others?

A: That's a great question and one that is answered in a couple of different ways in my mind. It's probably a different answer in the near term, the next 50 years, than in 200, 300, 400 years from now. In the near term, I come back to the idea that we have precedent for how we maintain visibility and responsibility for all kinds of people and entities today who are operating remotely and are subject to the laws of the countries that they're based in. Under the Outer Space Treaty as it is today, a U.S. company is subject to U.S. law and has been authorized by the U.S. government to go to this place — to the moon or Mars — to undertake this activity, and so it would seem to me that companies should be planning for the idea that they are still

▲ Blue Origin founder Jeff Bezos has championed the idea of millions of people living in habitats in low-Earth orbit. This illustration is one example of the concept, called O'Neill cylinders after the late Princeton physicist Gerard O'Neill. He concluded these habitats allowed for better conditions than the surface of other planetary bodies including Mars.

NASA Ames Research Center/Rick Guidice

"I don't necessarily see us coming internationally together to change or develop a whole new Outer Space Treaty."

subject to U.S. law and regulation with regard to labor practices. For any of these activities, a key aspect of success will be the ability to communicate back and forth. Right now, it's at least six months to get to Mars — at the point where we have industrial activities on Mars, is it still six months to get there, or have we somehow managed to get that time down significantly so it's a couple of days? Quite a few of those technological solutions are going to also address some of the concerns you bring up so people can communicate in the same way they can communicate today on Earth when they're concerned about the level of work that they're being asked to undertake and communicate with their employer. In the near term, I think we're likely to see that the long arm of the law applies, where you would be subject to your national jurisdiction. Now, different countries have different labor laws, and we already have a situation where some countries are flags of convenience for various activities. So can people take advantage? Unfortunately. That's true here on Earth, and it could be true on another planet. That said, the opportunities are there for the long arm of the law to apply and be applicable to those kinds of issues, particularly when the authorized entity is coming from a country like the U.S. that has a sophisticated legal regime.

Q: How do you think international disputes or sanctions might play out? Take the Russian anti-satellite test last November. There's always a lot of condemnation around those activities, but the sanctions don't always take the most direct forms.

A: The honest answer is that these are challenges that we still face terrestrially, and the more work we do to figure them out within the orbit of this planet, the better we will be situated for exploration in the future of the moon, Mars and beyond. These kinds of challenges aren't going to go away. I think that the answer is that the same mechanisms that we have today are probably extrapolated to the questions that you're asking with regard to planetary exploration in the future, in that there are only so many tools in a diplomat's toolbox. A country's toolbox has sanctions all the way up to escalations of armed conflict, and there's been thankfully more and more interest in finding solutions that do not involve armed conflict. And an international body like the United Nations, it is limited. In some cases, we have courts of justice within the U.N. that have been established, but there are parts of that process that some countries have not signed on to. But we do have other avenues like the World Trade Organization, where we resolve conflicts and nations represent each other and the activities that they represent. We come together and we actually have a forum where a decision is made and a ruling is made on a particular issue, so it is possible that we could come up with some dispute settlement mechanism for space that doesn't necessarily exist today. I understand that it's not always the most satisfying answer, but it's really amazing all the ways we have found to interact — companies

▲ California startup Relativity Space's goal of 3D printing entire rockets is an example of the technologies that will help make in-space settlements a reality, says Caryn Schenewerk, the company's vice president for regulatory and government affairs. The company is printing the majority of components for its Terran rockets out of a proprietary metal alloy via the Stargate printers pictured here. The first Terran is scheduled to launch later this year from Cape Canaveral, Florida.

Relativity Space

interact with other private companies, how countries interact with other countries — and resolve conflicts on a minute-by-minute basis on this planet. There are a lot of positive aspects of that, and in some cases, humans created these mechanisms in response to other issues. Maybe I'm a bit optimistic, but we've made progress — sometimes two steps forward, one step back, maybe — in ways that I think are indicative of a hopeful situation for planetary exploration.

Q: What makes you hopeful we can find consensus in space when it's been so difficult to do on Earth?

A: I'm going to come back to two key aspects of how international law is developed: opinion and practice. Anti-satellite testing is a great example of this. When a country takes an action and that country's ASAT test purposely doesn't hit a target, that action might be met with a level of opinion: "OK, we're not excited that you're developing this activity, but it's not so bad because you didn't create a huge debris cloud that's going to spread and be up there for decades." Compare that to the response when a country undertakes an ASAT test and actually blows something up. We've seen an increased level of opinion specifically saying, "That's unacceptable." After the Russian test in November, there's been an escalation of opinion leading up to the U.S. declaration to not undertake this activity anymore and positive opinion around that declaration. So we see people taking actions and then how we respond to those actions as an international community is part of how the law develops. That approach is also indicative of how this would be extrapolated to activities on other planets.

Q: Where do you think the first in-space settlement will be created: LEO, the moon or Mars?

A: I leave these questions up to the technical experts. I stand ready to help figure out what the framework looks like and how we achieve that, changes in law or compliance with the law. I do see a lot of progress happening with regard to commercial LEO capabilities and habitats, and that's really exciting. That's a step that needs to happen in the direction of further exploration. The activities that we see happening with regard to the moon and Mars right now do seem to be NASA-led, which I think is right and likely to continue to be true. NASA just put forward its 50 objectives for moon to Mars and what does it look like to be able to support activities and take advantage of private capabilities and engage internationally for going from the moon to Mars. So if somebody asked, "Caryn, how are you prioritizing legal issues that need to be solved?," my inclination would be tackling the things that need to happen to make sure that we're able to do that LEO commercial activity and then moon and then Mars beyond that. I see a natural progression where you start solving some of those problems and they start extrapolating out to serve the benefit of all those exploration needs. ★

What goes up...

In-space manufacturing is reaching a crucial point. Dozens of companies are now developing technologies to make use of the microgravity environment to beat the efficiency and quality of goods and materials made on Earth. The question has been how to bring products home safely in sufficient quantities. Jonathan O’Callaghan tells the story of two startups vying to show the way.

BY JONATHAN O’CALLAGHAN | jonathan.d.ocallaghan@gmail.com

Getting stuff into space has never been easier. SpaceX, Rocket Lab and other launch companies have vastly lowered the cost of going to space and increased the rate of launches, with 135 launches in total in 2021 — more than any other year in history.

Yet while space is the most accessible it's ever been, coming back is more difficult. At the moment, the only U.S.-made vehicles capable of bringing anything back are SpaceX's Dragon spacecraft. Not quite ready yet are Boeing's Starliner capsules and Sierra Space's Dream Chaser spaceplanes, and of course Russia has its Soyuz capsules and China its Shenzhous.

Much more return capacity will be needed for entrepreneurs to springboard in-space manufacturing into a capability that can transform entire industries on our planet. So far, the ability to make useful items in space, such as optical fibers that can be made into cables, has been demonstrated on the International Space Station. Enough material has been

> “The ability to get more down-mass options on demand, as opposed to waiting months, would be very attractive.”

— Mike Gold, Redwire Space

◀ SpaceWorks is now preparing to test its re-entry method from low-Earth orbit after completing two high-altitude drop tests. The most recent occurred in October, when a capsule test article (above) fell from an altitude of 32 kilometers and made a gentle parafoil-assisted landing.

SpaceWorks

brought home aboard the Dragons to show the promise of in-space manufacturing, and now, startups are eyeing novel and cheaper ways of getting material back from space.

“It’s absolutely an exciting time,” says Shelli Brunswick, chief operating officer of the Space Foundation in Colorado. “The possibilities are endless.”

Mary Poppins

Today, cargo returning to the U.S. from ISS must fit on racks or inside compartments aboard the van-sized Dragon capsules. And there’s a wait, with such returns only happening every few months at best. Anything made in space, therefore, currently faces lengthy delivery times.

In the United Kingdom, however, one startup has another idea. Called Space Forge, the company based in Cardiff is developing a method to protect each of its reusable small spacecraft as they plow through the atmosphere. If successful, materials and products could be made in orbit and dropped back to Earth as needed, without having to schedule a trip on a Dragon, or someday a Dream Chaser or Starliner.

“We’re building the world’s first returnable and relaunchable satellite platform,” says Joshua Western, the company’s co-founder and CEO. “We’ll be able to scale in-space manufacturing to a position where it’s economically viable.”

The company plans to soon launch a small demonstration spacecraft called ForgeStar-0 from the U.K. on an air-launched Virgin Orbit rocket in what would be the first orbital launch from the country. The spacecraft will test the company’s proprietary re-entry shield, which during future operational missions would protect a satellite traveling through the searing heat of the atmosphere, targeting a landing ellipse of just hundreds of meters. While the exact technology is under wraps, Western says each shield has an “umbrella-like” deployment, unfurling upside down ahead of the spacecraft to start. Then, once through the thick atmosphere, the shield doubles as a parachute, slowing the spacecraft for a gentle touchdown.

“I describe it as Mary Poppins from space,” says Western.

ForgeStar-0 will be purposefully oriented to burn up in the atmosphere, providing useful data points about how the shield copes with re-entry. But a true test will come possibly as early as next year, when the company launches its ForgeStar-1 satellite to demonstrate in-space production of semiconductors, which have a 10-to -100-time performance improvement over semiconductors made on Earth.

“You can reduce the energy consumption of major infrastructure by more than 50%,” says Western.

Space Forge is being taken seriously. In 2021, it closed Europe’s largest seed-funding round for a space company, raising $10.2 million. The company hopes to begin commercial operations by the end of 2023 at the earliest.

“They’re envisioning manufacturing facilities in space that can produce flawless electronics, exquisite metal alloys and perfected pharmaceuticals,” says the Space Foundation's Brunswick. “The cost-benefit analysis is exponential.”

Pulling strands of ZBLAN (zirconium barium lanthanum aluminum sodium fluoride) into fibers to create fiber optic cables is an early candidate for in-space manufacturing. Demonstrations on the International Space Station have resulted in smoother fibers (left) than those made on Earth (right), which often form bubbles and crystals that reduce transmission.

NASA

Special delivery

In the U.S., another company is hoping to achieve a similar goal, albeit by slightly different means. SpaceWorks of Georgia is designing a more traditional return capsule with funding from NASA. The idea is that the capsule would pass through the atmosphere, protected by an ablative heat shield, then deploy a guided parafoil to gently lower itself to the ground.

In October 2021, the company tested a prototype of its RED-4U capsule — RED stands for Re-Entry Device. The capsule dropped from a balloon at an altitude of some 32 kilometers (100,000 feet) and deployed its parafoil, simulating the final stages of re-entry and landing.

"That last 100,000 represents the re-entry conditions that we'll see from space," says John Bradford, the company's president and chief technology officer.

SpaceWorks ultimately plans to launch larger

versions of its capsules to orbit. Each would be launched by a conventional rocket, and once released, a booster module would send it to ISS or to one of the planned private stations. The capsule would enter the station airlock and be collected by astronauts.

"They could just bring it inside," says Bradford, and pack it with space-made materials or products for return to Earth. For return, crew members would push the capsule back out of the airlock, and its booster module would propel it toward Earth.

SpaceWorks is also designing a free-flying version of the capsules. A manufacturer could install production hardware in the capsule and make the materials or products on orbit, and then the capsule would bring the payload down to Earth.

"We can go up to about 120 days in orbit," says Bradford. The company is targeting a suborbital test in 2023 before beginning orbital operations in 2024.

SpaceWorks ultimately hopes to have one capsule returning every week, while SpaceForge is aiming for about one a month.

What could drive such a high cadence? One possibility is ZBLAN, short for zirconium barium lanthanum aluminum sodium fluoride. This glass-like material can be robotically pulled into strands and bundled to form fiber optic cables with a wider range of frequencies than Earth-made cables comprised of silica fibers. A handful of companies have produced ZBLAN on ISS, including Made in Space. Another California company, Fiber Optic Manufacturing in Space, is currently manufacturing such fibers and forming them into cables via a remotely controlled machine in the station's Destiny Lab, which can produce a kilometer of cable in just "minutes to hours," says Leo Volfson, owner of Torrey Pines Logic in California, which builds the machine for FOMS.

But Made in Space's parent company, Florida conglomerate Redwire Space, also sees a much wider demand. The company has tested a host of in-space technologies in orbit including tissue growth equipment.

"Biotech is the low-hanging fruit," says Mike Gold, Redwire executive vice president for civil space and external affairs. "It's an existing market, there's a great deal of need, and there's vast quantities of money."

And while much progress has been made, having additional methods to return material from orbit could be invaluable.

"We could certainly use more," says Gold. "The ability to get more down-mass options on demand, as opposed to waiting months, would be very attractive."

All eyes now will be on Space Forge and SpaceWorks, to see if their efforts can be successful.

"Everyone's been focused on sending things up," says Bradford. "Now we're starting to think about bringing things back." ★

▲ Rather than an ablative heat shield flush against the spacecraft exterior, Space Forge of the United Kingdom is opting for a shield that deploys like an upside-down umbrella, shown in this rendering. Once the spacecraft passes through the atmosphere, the shield would act as a parachute.

Space Forge

COVER STORY

HYDR

Hydrogen-powered aircraft could prove to be the best way for the air travel industry to meet its bold commitment to net-zero carbon emissions by 2050. For that to happen, hydrogen must be stored safely on these next-generation aircraft, and the question is the best way to do it. Karen Kwon tells the story.

BY KAREN KWON | ykarenkwon@gmail.com

OGEN

COMING TO AN AIRCRAFT NEAR YOU

▲ Airbus released these hydrogen-powered aircraft concepts in September 2020 when it announced its ZEROe initiative to have a hydrogen airliner ready for passenger flights in 2035. Results from ground and flight tests the company plans to conduct over the next several years would help choose the design of the operational aircraft, which could be entirely different from the concepts shown here.

Airbus

Most executives like to use specification sheets to illustrate the benefits of new products. Paul Gloyer likes to show a photograph. In it, two kindergarten-aged children clutch the ends of a black cylindrical tank at least 10 times their size, lifting it off the ground with ease.

"This is a really good example of highlighting how light the tank is," says Gloyer, president of Gloyer-Taylor Laboratories, or GTL, a Tennessee aerospace research and development company. The girls in the photo are children of a company employee.

Gloyer's composite tanks are among those in the works by a handful of companies vying against metallic versions as the best method of storing molecular hydrogen as an aviation fuel. Researchers know they must get that answer right if hydrogen-powered aircraft are to lead the way in decarbonizing air travel. At stake could be whether the air travel industry meets its commitment of achieving net-zero carbon emissions by 2050, a target set in 2021 by the International Air Transport Association, an airline membership organization.

Molecular hydrogen is an attractive option because, whether combined with oxygen in a fuel cell to create electricity to power motors or combusted in liquid or gaseous form, the main byproduct is water vapor. While both water vapor and carbon dioxide contribute to atmospheric warming by trapping heat radiating from the Earth, water molecules remain in the atmosphere a handful of days before dissipating or falling to Earth as precipitation instead of lingering for decades as carbon dioxide molecules do. Not only that, hydrogen molecules unleash three times the amount of energy of traditional jet fuel by mass.

But that advantage is offset by a volume conundrum: It would take 3,000 liters of unpressurized, ambient-temperature gaseous hydrogen to release the same amount of energy as a liter of conventional jet fuel, according to Airbus, which is studying aluminum fuel tanks for a future hydrogen passenger airliner. This volume could be reduced by pressurizing hydrogen and storing it at cryogenic temperatures to keep it in a liquid state. But even then, it would take four liters of hydrogen to deliver the punch of a liter of jet fuel. The fuel tanks would still be too large to fit inside an airliner's wings and center section, which is the common

strategy today.

Success will largely depend on designing and building lightweight tanks that can carry large amounts of liquid hydrogen and meet the industry's lofty standards for passenger safety. Airbus and other companies pursuing aluminum and other metallic designs are betting that these widely used materials offer the quickest route to bringing hydrogen-powered aircraft to market, while Gloyer is among those who believe composite tanks are the best way to meet the weight goal.

Weighing the challenge

Just the basic premise of a hydrogen fuel tank makes the extent of the challenge apparent. Packing the molecules together in liquid form and keeping them that way requires extremely low temperatures — at least minus 253 degrees Celsius. This in turn calls for a multilayer tank that needs, for long-distance flights, an active cooling system that basically works like a refrigerator by circulating cryogenic fluid such as helium gas through high and low pressures.

All these extra parts, of course, would add more weight to a design and reduce the amount of fuel that can be carried.

"Looking at tank mass, there's been discussion of composite tanks versus metallic tanks," says Wesley Johnson, a NASA engineer whose focus is on cryogenic technologies. In the past, NASA has used cryogenic tanks made from composites for various spacecraft, "but there's different requirements on the airplane side that may drive how you design and develop those." Hydrogen tanks for aviation must endure multiple uses, for example.

Gloyer's GTL company sees its carbon fiber composite design as a way to keep the tanks light enough for aircraft of all sizes, from turboprop planes and jets that conduct regional flights to the large passenger airliners needed for long-haul travel. Located near the University of Tennessee Space Institute, GTL has until recently mostly concentrated on building space hardware, especially on reducing the propellant tank mass for launch vehicles. Then, "a few years back, we had some customers in the aviation industry come to us and say, 'Your technology that works for cryogenic propellants for rockets, can that work for hydrogen for airplanes?' And we were like, 'It should,'" Gloyer says.

▲ Gloyer-Taylor Laboratories of Tennessee decided carbon fiber composites were the best material to craft its lightweight hydrogen fuel tank. Each tank would hold about 150 kilograms of liquid hydrogen and weigh 12 kilograms when empty, about as much as a cocker spaniel.

Gloyer-Taylor Laboratories

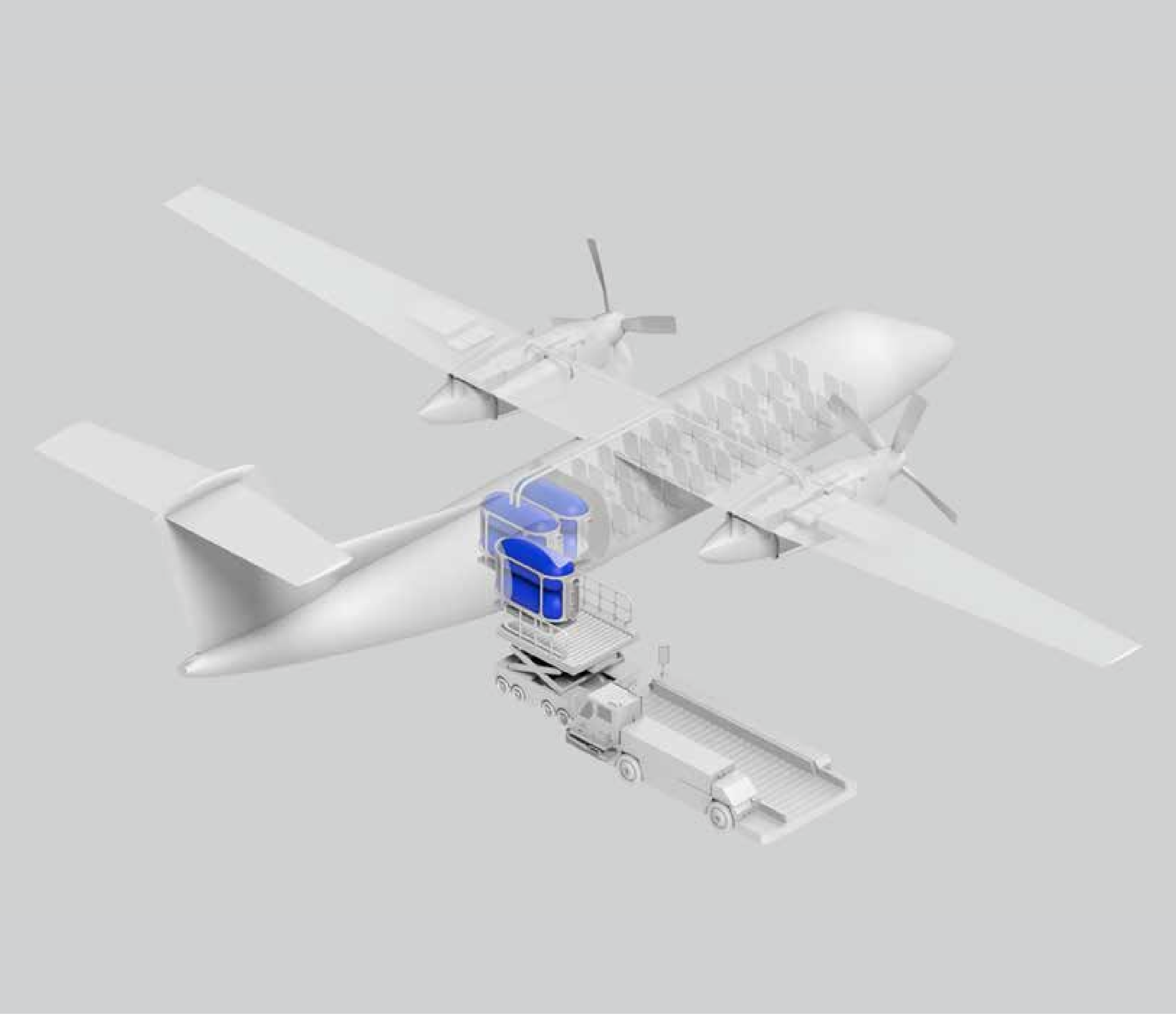
"There's a lot of people doing demos right now where they put the hydrogen in vehicles, they basically take off, fly for a few minutes, and then they land because they're out of fuel. The hard part is having enough fuel to go far."

— Paul Gloyer, Gloyer-Taylor Laboratories

That pivot has worked in the company's favor. GTL announced in March that it had built a 2.4-meter-long cryogenic tank — the same one that the two girls were lifting in the photo. Weighing in at 12 kilograms when empty, the tank weighs a quarter of what the other state-of-the-art aerospace cryogenic tanks weigh, according to Gloyer. And to keep the inside temperature of the tank from rising during flight — which would result in boiling, turning the liquid hydrogen into gas — the tank is double-walled with a vacuum in between the layers to reduce heat transfer from the tank's exterior.

For the insulation, many manufacturers apply spray-on foam insulation. "All of that gets really heavy," Gloyer says. "The best way to do it is with a vacuum-insulated system, like a Yeti cup," which also relies on a double-walled design to minimize heat transfer.

Based on his review of published specifications from other companies, U.S. Department of Energy reports and what GTL's customers have shared about the performance of competitors' tanks, Gloyer says that typically, only 5% to 7% of the total weight of a tank comes from the fuel itself. The rest is due to the tank structure, though some are now reporting 10% to 12% thanks to the industry-wide push for higher



hydrogen percentages. But the hydrogen fraction is much higher for GTL's new tank: 60% to 70%.

"So what that ends up meaning is that for the same 100 kilograms with our tech versus somebody else's tech, you can carry 10 times as much hydrogen fuel as you could with current technology," Gloyer says. "That's the game changer."

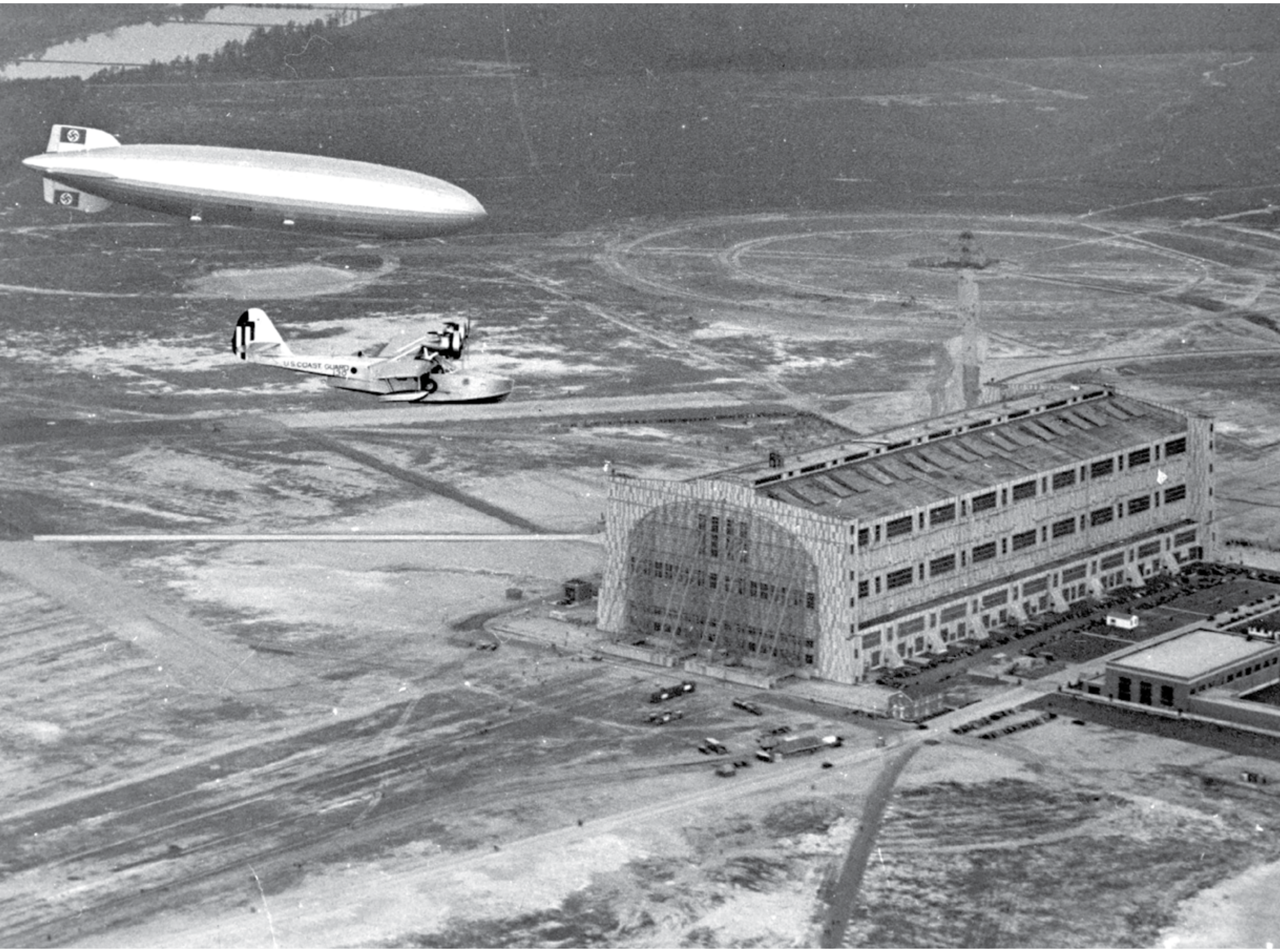
GTL in March announced it would sell its tanks alongside fuel cell stacks from HyPoint of California to aircraft manufacturers. According to HyPoint's internal analysis, pairing GTL's 150-kilogram tank with HyPoint's fuel cell stacks would almost triple the range of a 50-seat De Havilland Canada Dash 8 Q300 to 4,500 kilometers, compared to the 1,500-kilometer-range the same plane would have with its two turboprop engines burning conventional jet fuel.

Separately, Gloyer says GTL is in discussions with several customers to conduct flight demonstrations with the new tank in vehicles including airships, helicopters and airplanes. The company is also planning an in-house flight demonstration of a liquid-hydrogen-powered hovering drone in 2023.

One of the goals of these demonstrations is showing off the increased range that is possible with GTL's design, Gloyer says. "There's a lot of people

▲ Universal Hydrogen is designing gaseous and liquid hydrogen capsules as part of a kit for converting turboprop planes to hybrid-electric aircraft. The capsules would power two electric motors built by magniX of Washington, with a collection of fuel cells providing additional thrust.

Universal Hydrogen



doing demos right now where they put the hydrogen in vehicles, they basically take off, fly for a few minutes, and then they land because they're out of fuel. The hard part is having enough fuel to go far."

And the lighter the tank, the more fuel the aircraft could carry, which would reduce the operating cost per passenger for airlines. Gloyer says that according to his calculations, the GTL tank would make it cheaper to operate regional jets and long-haul aircraft on liquid hydrogen than conventional jet fuel.

"So you end up with a new paradigm" where the switch to hydrogen would be driven by financial incentives in addition to the desire to reduce carbon emissions, he says. "You'll be stupid not to transition to hydrogen."

Betting on metal

Despite the potential for lighter-weight designs that composites afford, Airbus is one of the companies sticking with metallic tanks for the time being. As part of its ZEROe initiative to design and build a hydrogen passenger airliner that would begin service in 2035, the company is developing cryogenic aluminum tanks at its various Zero-Emission Development Centers throughout Europe.

"Maybe in the future, we will explore CFRP [carbon-fiber-reinforced polymers]-like tanks," says Mathias Andriamisaina, head of Airbus' ZEROe demonstrators. "But for the moment, we are looking at metallic."

He says that the weight of the tanks could be reduced by getting rid of the active cooling system and changing the type of insulation inside the tank, to name a couple strategies. Plans call for installing four of these aluminum tanks on an A380 test aircraft Airbus is modifying into the ZEROe demonstrator. In the first round of test flights scheduled for late 2026, liquid hydrogen in the tanks would be direct-

▲ The Hindenburg, left, approaches Lakehurst Naval Air Station, New Jersey, in 1936. The airship burst into flames and fell to the ground a year later while attempting to land at the same station, the most likely theory being that an electrical discharge ignited the airship's skin, which in turn ignited leaking hydrogen fuel.

U.S. Coast Guard

> **“Safe hydrogen is just a matter of taking the right precautions and using the state-of-the-art technologies.”**
>
> **— Mathias Andriamisaina, Airbus**

ly combusted in a modified turbofan engine from CFM International, a joint venture between GE and Safran.

Similarly, California startup Universal Hydrogen plans to use aluminum to construct the liquid hydrogen tanks that would be part of the company’s first product: retrofit kits for converting today’s turboprop regional planes to hybrid-electric ones. The company wants to begin selling the kits — consisting of the fuel tanks, electric motors from magniX of Washington and fuel cells from Plug Power in New York — to regional airlines in 2025.

“We don’t really need to go to composite tanks to solve the regional aircraft — the problem that we’re trying to address now,” says Mark Cousin, chief technology officer at Universal Hydrogen.

That doesn’t mean that the company is ditching composite materials completely, however. Universal Hydrogen is also constructing composite tanks for gaseous hydrogen. Because it does not need to be kept at cryogenic temperatures, the fuel is easier to store and transport in that form. The gaseous tanks could also power collections of fuel cells or electric motors for regional aircraft conducting shorter-range flights. These high-pressure vessels would consist of inner and outer layers made from carbon fiber, either wound or braided around a plastic or metallic liner, according to Cousin.

Ultimately, the decision of whether to choose metals or composites will come down to a variety of factors, Johnson the NASA engineer told me by email. Some companies may consider the composite tank technology not mature enough and therefore risky for near-term applications, or that one material works better than the other for a particular aircraft market.

Companies will ask themselves these questions and more as they refine their tank designs, he said. That’s “part of the technology development cycle.”

"With a metallic-type design, we're really not inventing anything new. We don't have any particular problems with the materials for a metallic cryogenic tank."

— Mark Cousin, Universal Hydrogen

For Universal Hydrogen, the reason is quite simple: metallic tanks are well-understood. "With a metallic-type design, we're really not inventing anything new," Cousin says. "We don't have any particular problems with the materials for a metallic cryogenic tank."

New airframes for new tanks

Regardless of what they are made of, there is at least one thing that the various hydrogen tanks will have in common: their shapes.

"It's better to have something which is cylindrical or spherical and not having something which is square or flat" like the fuel tanks in today's airliners, says Airbus' Andriamisaina. And this isn't just true for hydrogen; manufacturers favor cylindrical tanks for storing many kinds of gas because the shape evenly distributes pressure across the tank, improving storage efficiency.

This new shape requires a departure from the centurylong method of placing fuel tanks in the wings of regional jets and, in the case of passenger airliners, also in the center section. Instead, hydrogen tanks would need to be placed in the fuselage. Airbus' current plan places the tanks in the rear part of the fuselage, Andriamisaina says, though he adds that the design has not been finalized. For regional jets, Universal Hydrogen is also planning to do the same by removing a few seats from the back of the aircraft.

"So we're reducing a 70-passenger airplane to a 55-passenger airplane, for example," Cousin says.

Storing hydrogen tanks in an aircraft's fuselage could sound scary to passengers as hydrogen, like other fuels, is highly flammable and could easily be ignited. Something unique is the extremely small size of the hydrogen molecules. This means some could escape the container, even slipping through the densest potential tank material of all, a layer of steel. But Johnson and the other experts say there

aren't undue safety concerns for hydrogen, especially since other industries have been using hydrogen safely for decades.

"We believe that hydrogen is as safe as kerosene," Andriamisaina says.

He adds: "We will never make any compromise on the safety. I can tell you, when I make my project objective, safety is the objective No. 0" — the absolute top of the list.

To ensure safety, Airbus plans to place active detection sensors for hydrogen and oxygen in the ZEROe demonstrator that would be capable of detecting any leaks in milliseconds. Additionally, the hydrogen valves will be insulated to prevent leakage, and there will be active and passive hydrogen ventilation systems to avoid hydrogen from concentrating in any part of the aircraft.

"Safe hydrogen is just a matter of taking the right precautions and using the state-of-the-art technologies," he says.

NASA's Johnson says history has unfairly tainted the American public's view of hydrogen. Even though there have been successful hydrogen-powered flights in the past — most notably the Soviet Union's Tu-155 airliner that first flew on hydrogen in 1988 — the phrase "hydrogen aviation" conjures up images of the 1937 Hindenburg airship disaster that killed 36 people.

Despite the obstacles, Cousin makes a bold prediction.

"I think by the end of this decade, [hydrogen] will be a major player in the regional aircraft business," he says.

And once that happens, public pressure will grow for Airbus and Boeing to craft new hydrogen-powered designs for the single-aisle market.

"If companies expect to be able to launch an airplane in 2035 that still burns dinosaur juice, I think they're going to find that that's difficult to do," he says. ★

▲ This illustration depicts Airbus' first round of flight tests with the ZEROe demonstrator, a modified A380 aircraft that will help guide the design of Airbus' future passenger airliner. Plans call for flights in 2026 in which a hydrogen combustion engine on the demonstrator's rear fusalage would burn liquid hydrogen fuel from four 100-kilogram tanks located inside the fuselage.

Airbus

EMISSIONLESS AIR TR

HOW IT MIGHT BE ACHIEVED

AVEL

The air transportation industry wants to achieve net-zero carbon emissions, but its strategy does not include emissonless aircraft. While no one can guarantee the feasibility of such aircraft, especially for long-range flight, NASA's Dennis M. Bushnell says untapped aerodynamic innovations show tremendous potential toward that goal.

BY DENNIS M. BUSHNELL

The air travel industry's current efforts to make long-range air travel kinder to the climate are laudable, but they have an Achilles' heel: The ideas broached so far would not eliminate aircraft emissions. Today's turbofan jet engines can burn any of a growing list of approved sustainable aviation fuels made from non-fossil fuel feedstocks. The combustion products from burning these sustainable fuels, however, are similar to when the engines burn conventional fuel. The climate benefit comes from recycling carbon, but today that is done at nowhere near 100%. Next-generation engines might burn hydrogen or operate as hybrids with electricity generated by hydrogen fuel cells, but those aircraft won't be emissionless either. When they ingest air for combustion, the exhaust will consist of nitrogen oxides and water vapor, which when deposited above the tropopause can form cirrus clouds that block infrared energy emitted from the surface and produce an even larger warming impact than carbon dioxide.

Maximizing air transportation's efforts to reduce climate forcing will require introducing emissionless aircraft capable of carrying significant numbers of passengers at increasing ranges. Such aircraft represent the frontier of what can be responsibly imagined, but we must stretch our thinking into this realm. To use a pugil analogy, the time has come to take the gloves off in our field to address climate change.

Achieving emissionless flight at ever-increasing ranges will require innovations in aerodynamics, materials and battery electrics to include the improvements in energy density promised by lithium-air, so called because such designs ingest air from the atmosphere. While not ready yet, li-air batteries would be dramatically lighter than today's lithium-ion versions and, in one estimate, could store seven times more electricity. In the run-up to li-air, we are seeing the development of metal-air and solid-state batteries with greater energy density than lithium-ion.

It's conceivable that the flight range of a given battery capability could be doubled by employing frontier aerodynamics to dramatically increase lift-to-drag ratio. Work at Northrop in the 1950s by Swiss aerodynamicist Werner Pfenninger, and later by researchers at Virginia Tech, resulted in strut and truss-braced configurations that would at least double the lift-to-drag values but have yet to be implemented for air transport. In the next generation, new aerodynamic

configurations, perhaps including strut and truss-braced approaches, could be adopted to vastly increase the lift-to-drag ratio for long-range passenger aircraft, whether those aircraft are powered by sustainable aviation fuels, hydrogen, hybrids or batteries. Doing so would further reduce carbon footprints and increase the range of those aircraft while research proceeds toward the stretch goal of long-range emissionless aircraft.

Here are the most promising aerodynamic and materials innovations to incorporate:

With few exceptions, today's passenger aircraft do not yet seriously employ laminar flow control to reduce the approximately half drag factor that comes from surface friction. A small passenger aircraft, the Celera 500L, has incorporated an initial laminar flow fuselage for drag reduction. For swept wings, laminar flow control requires suction, which adds additional weight, complexity and cost. Employing externally truss-braced wings, on the other hand, enables the wing to be thinned and its sweep angle reduced so that natural, or pressure gradient, laminar flow control can be employed. The wing truss also provides external structural support to reduce wing weight and significant increases in the wingspan, with outboard wing hinges available to accommodate the parking boxes at airport gates. This increased wingspan much reduces the 35% of aircraft drag that is due to the wing tip vortex formation, termed drag due to lift, which rotates part of the wing lift into the drag direction. Increasing span reduces the portion of the wing affected by the tip vortex.

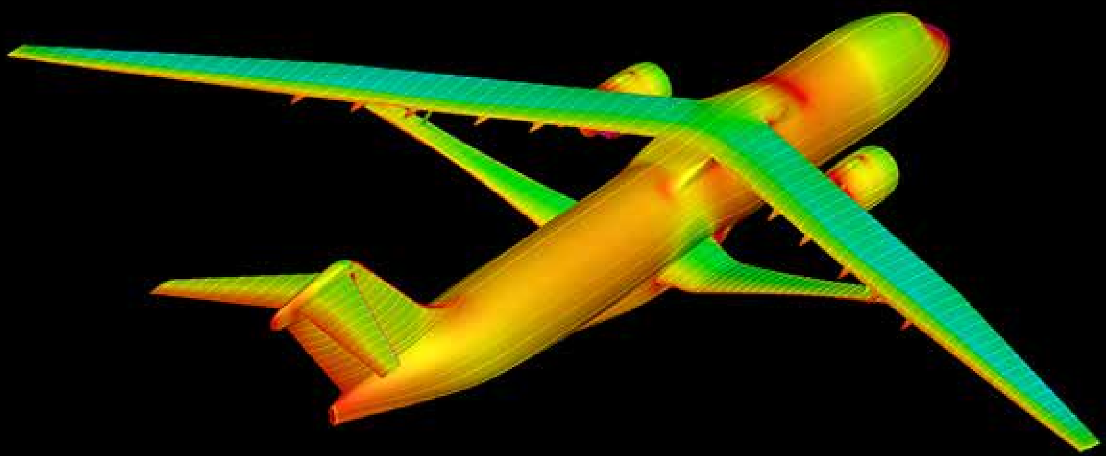
Also, small longitudinal surface grooves, termed riblets, could be incorporated to reduce the friction drag of surfaces with turbulent flow by up to 10%.

Then there is the very promising ongoing research on plasma turbulent drag reduction approaches, with some 65% reduction in turbulent friction drag achieved thus far, a veritable aerodynamic revolution. Also, locating engines at the rear and utilizing thrust vectoring for control, rather than mechanical elevators or rudders, would obviate the weight and drag of the empennage.

In addition, industry designers could take advantage of trends in weight reduction. There is an ongoing revolution at MIT, NASA and elsewhere toward lighter-weight materials. These include nanocomposites and nano-printed metals, the latter producing superb material microstructures. Advances also are being made toward making the aircraft's structure double

▲ Otto Aviation of California incorporated laminar flow control into the fuselage of its Celera 500L general aviation aircraft, reducing drag and fuel consumption.

Otto Aviation



A truss-braced wing is among the aircraft configurations NASA and manufacturers have studied to reduce aircraft fuel burn and emissions, in this case by reducing the amount of drag on the wings. This computational fluid dynamics simulation of a TBW aircraft illustrates that advantage, with the blue-green depicting areas of low drag and the red representing relatively few areas of higher drag.

NASA/Craig Hunter

as a battery. As for landing gear, their weight could be reduced by incorporating drag parachutes into operations, alleviating the need for heavy brakes. These parachutes could be deployed in the event of a refused takeoff. Automatic gentle landings would permit the gear to be of a lighter construction. To make truss-braced wings as light as possible, there has been initial consideration in academia of using an inflatable inner wing section. Truss-braced wings already reduce wing weight, due to the external structural support. Utilizing thrust vectoring in lieu of an empennage also would save weight.

The following describes a transport aircraft configuration that would nominally double lift-to-drag ratio by incorporating these innovations:

- A truss-braced wing with doubled span, reduced sweep and thickness, enabling a large drag-due-to-lift reduction and large area of natural laminar flow, and therefore low friction drag.
- Engines or motors moved to the rear. Thrust vectoring would provide control, eliminating the weight and drag of the empennage.
- Fuselage boundary layer engine intake. This design element would increase propulsion efficiency as is well known. It could be configured to produce favorable aerodynamic and propulsion interaction, reducing the effective fuselage drag.
- The fuselage for a small transport would be configured for natural laminar flow, as a current effort has demonstrated. A large transport would employ suction boundary layer relaminarization downstream of the forward passenger door, plasma turbulent drag reduction on surfaces with turbulent flow and digital view screens for the pilots and passengers instead of windows, along with some wall suction for laminar flow control on the fuselage. If the aircraft is powered by hydrogen and that hydrogen is stored cryogenically, cooling of the aircraft wall would be employed to laminarize the fuselage boundary layer.

Preliminary evidence suggests that li-air batteries combined with these approaches could provide fully emissionless ranges approaching 10,000 kilometers. NASA, academia and industry should explore this promising frontier, developing passenger aircraft that are battery-electric with increasing range as advanced batteries and low-drag aerodynamic approaches are deployed. Nearer term, emissionless passenger aircraft would have sufficient range to subsume some half of aircraft travel. ★

Dennis M. Bushnell is chief scientist at NASA's Langley Research Center in Virginia.

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AIAA
SHAPING THE FUTURE OF AEROSPACE

A post-pandemic plan for aerospace education

Educators and students managed to keep progress going through the pandemic with remote learning. Now it's time to get back to largely in-person learning that leverages the best of remote learning. Amir S. Gohardani explains.

BY AMIR S. GOHARDANI

As they come out of the pandemic, school administrators and educators in the United States are facing a colossal task. The aerospace industry is counting on them to deliver the skilled, robust and diversified workforce capable of meeting current and future aerospace challenges, from exploring distant worlds and searching for life on other planets to shuttling passengers around town in electric air taxis or across continents in jets with a net-zero carbon footprint. The best way to do this will be to make a vigorous return to primarily in-person learning, with the pandemic's remote learning tools adopted in limited circumstances and with an understanding that remote learning is not flawless. The goal must be a learner-centric strategy that starts in grade school, progresses through secondary school to the college level and even into the workforce as employee-centric continuing education.

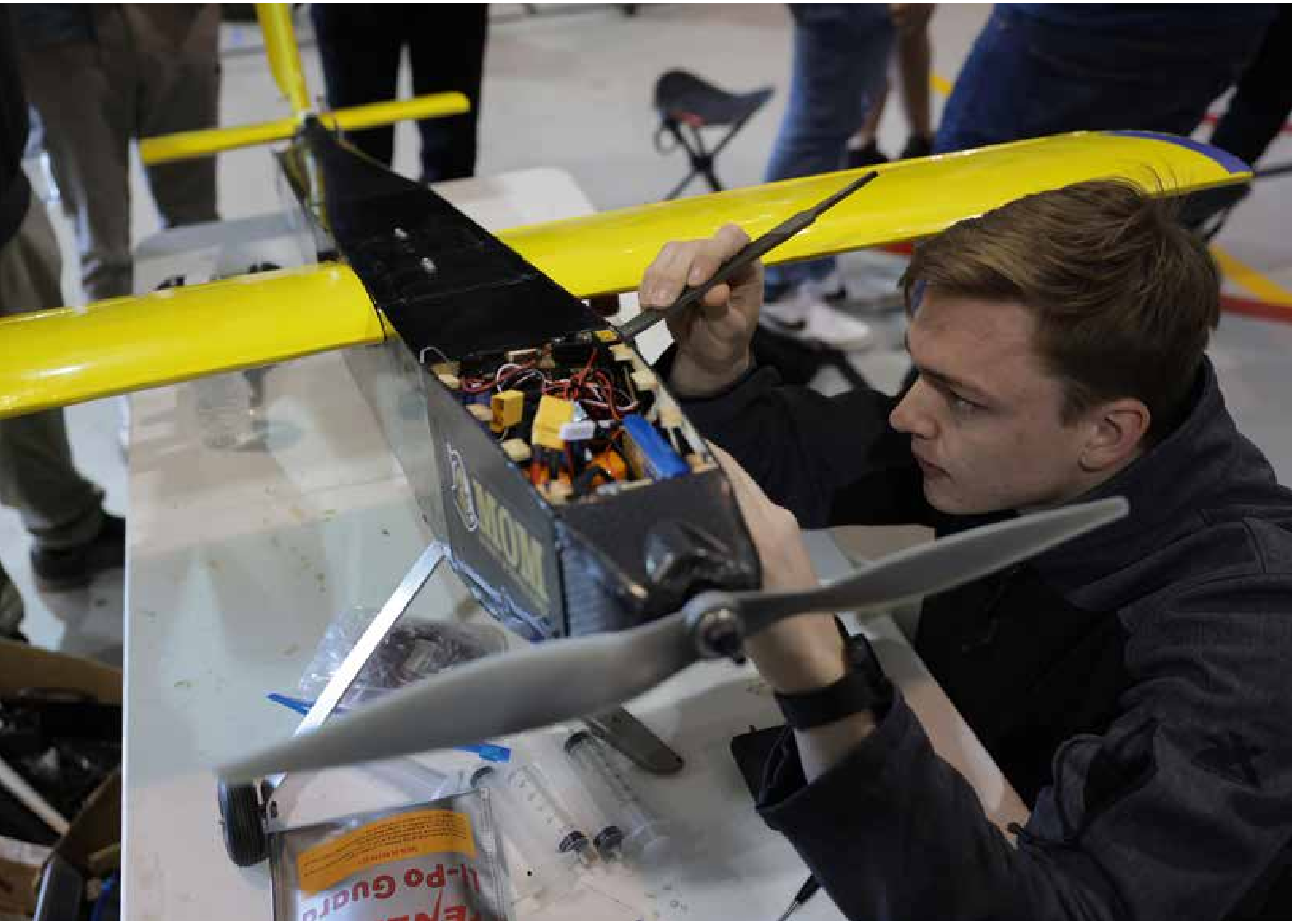
One might question whether there is a cause for concern, given the aerospace community's record during the pandemic of making the seemingly impossible possible. NASA flew the Ingenuity helicopter on Mars for the first time in 2021 in the first controlled flight in another planet's atmosphere; the Johns Hopkins Applied Physics Laboratory in collaboration with NASA launched the Double Asteroid Redirection Test spacecraft last year to set up what will be the world's first full-scale planetary defense test; the James Webb Space Telescope in January finished unfolding itself; in April, SpaceX launched an entirely civilian crew to the International Space Station. Also, passenger jets

Embry-Riddle Aeronautical University

accelerated their use of sustainable aviation fuels made from nonpetroleum sources.

If things are fine, why change them? These recent feats were, of course, largely a result of pre-pandemic education. Trouble was brewing even as they were being achieved. The total industry sales revenue dropped 2.8% to $874 billion in 2020 from 2019, according to the Aerospace Industries Association's "2021 Facts & Figures US Aerospace & Defense" report. And now, economists are warning of rising costs and slower growth.

Here in the United States, we'll need to sharpen education, and hence the aerospace workforce, to meet the challenges ahead. Only a well-educated workforce can propel an idea from a sketch on a paper napkin into a reliable product. And of course, we need as many as possible of these talented workers to stay in the field. Sadly that has not always been the trend. Take a study that investigated this exact matter: For a thesis project in 2019, Sara Oliveira Pedro dos Santos, then a Master of Science candidate at Iowa State University, surveyed 245 enrolled undergraduate students in aerospace engineering at Iowa State to find out why they chose the aerospace major and in some cases left it. Those who left the major viewed the narrow scope of the field and career outlook as concerns. Careers in space and aviation did not look as plentiful as they initially perceived them to be, and some cited difficulty of the subjects in the aerospace curriculum. Some, however, persisted in the field in full awareness of these challenges, which suggests that we need to do



▲ Students from the University of Central Florida were among the 700 who participated in AIAA's 2022 Design, Build, Fly event in April, the first in-person competition since 2019. Aerospace engineering professors often encourage participation in this aircraft-building competition as a way to gain hands-on experience designing planes to specific sets of requirements.

AIAA

all we can to equip students to persist. The ability to persist is shaped in part by the learning experience, and therefore creating a better learning experience should be a priority.

Creating a better learning experience

Learning is indeed a pathway for creating a robust and skilled workforce. But currently, the educational experience is in dire need of a change. Access to skilled educators is obviously essential, but in March, the Institute of Education Sciences, part of the U.S. Department of Education, reported that nearly 44% of public grade schools reported full- or part-time vacancies due to resignations and retirements. In the same month, an article published by the Brookings Institution think tank in Washington, D.C., highlighted "severe staff shortages" among the many different effects of the pandemic. Staff shortages and inaccessibility to qualified teaching personnel will affect the quality of teaching and, in turn, the learning experience for many years to come.

Now, more urgently than ever before, it is time to find ways to revitalize the educational sector. Work-life balance and compensation must be addressed. Despite their impactful roles affecting generations, K-12 teachers are often underpaid, overworked and overlooked.

High-quality teaching practices must be identified and nurtured. During my two decades of teaching K-12 and college-level courses in Europe and the United States, the best of us were those willing to relearn topics through the experiences of our students. Quality teaching produces impressive outcomes. I have witnessed K-12 students proposing innovative ideas such as monitoring wildfires with swarms of drones. Educators at the college level must have the opportunity to learn new teaching methods, and they must be willing to change their ways. In addition, administrators should recognize that someone who is a phenomenal researcher might need training to become a phenomenal teacher. Too often at the university level, priorities are in conflict as aerospace educators must struggle to balance teaching, research and the pressure to win grants.

Aerospace educators at the college level struggle with navigating a myriad of hurdles. A professor with several hundred in an auditorium cannot give the same personal attention to each student as one with 30 students in a classroom. Of course, no matter the size of the class, the teaching methods and sequence are the roots of success. If learners are placed front and center, and a learner-centered approach is adopted, better learning outcomes will be achieved.

This learner-centered approach means that administrators and educators in all educational institutions must recognize different types of learners. Some are kinesthetic, using body movement interacting with their environments when learning. Others are auditory, meaning they understand and remember spoken words more easily than written ones. Other learners are just the opposite, preferring to learn by reading and writing down notes. Visual learners learn best by reading or viewing pictures. These four widely accepted learning modalities — kinesthetic, auditory, reading/writing and visual allow for better decision-making while crafting lesson plans. A well-thought-out lesson plan incorporates different learning modalities so different learners can digest as much material as possible. Often times, tapping into several learning modalities is helpful to reinforce crucial takeaways.

Despite the many logistical and budgetary challenges, it is, therefore, possible to craft curricula that uphold established learning outcomes while also resonating with students. Educators can, for instance, adapt their teaching through anonymous polls. In a nutshell, this is how one such tool works: A question pops up on a screen. Students are asked to text in their answers. A unique number that also serves as the text number reserved for that specific poll ensures student anonymity. A few minutes after the posted question, all student answers populate the screen in real time. This provides the educator with an opportunity to address incorrect answers and fill in the voids of knowledge. The system then automatically highlights and displays the number of students who answered correctly out of the total number of participants. This is powerful, since the educator now can ensure that by the end of that specific session or by an envisioned milestone, everyone has had a chance to learn. This type of adaptive learning is very impactful to learners and allows educators to enhance the learning experience each session continually.

The human element in education

Often, persistence and grit in students start at a very early age. When I visit schools through the Springs of Dreams Corp., a nonprofit I co-founded a decade ago with a mission to enlighten society through knowledge and education, young individuals are often fascinated by all things aerospace. While this fascination persists in high school, college-bound students often worry about their ability to succeed in the science, technology, engineering and mathematics courses required for a career in aerospace engineering. Within this STEM curricula, some students exhibit a special fear of mathematics and physics. Exactly here is where educators can make a world of difference. In one of the lessons we held in a middle school in Orange County, California, students learned the basics of flow visualization. Supported by this foundation, we translated some of the concepts discussed into simple mathematical equations.

Not surprisingly, virtual learning settings skyrocketed during the pandemic. As we contemplate the future environments for learning, we should not forget about the human connection that can get lost in virtual worlds. This connection gains meaning beyond a screen and includes a deeper connection to the topics of study. All subjects cannot effectively be learned through a webinar or online lecture. For instance, while learning to code could work in a virtual setting, running experiments in a wind tunnel via similar settings is trickier. It is, however, possible to combine the experimental learning in a wind tunnel with additional online resources for learning a topic such as aerodynamics and access the best of both worlds.

Humans typically enjoy the presence of other humans, and this goes for both teaching and learning. In the future workforce, such a human-centric approach will be crucial, given that the tedious work is likely to be taken care of by artificial intelligence and machine learning software. Inventors and subject-matter pioneers will discover that they can catapult their ideas into high dimensions by learning to team. Lately, the nonprofit Project Management Institute has updated its exam for the Project Management Professional certification to focus on the people, process and business environment. The human dimension is of particular interest as it emphasizes the soft skills needed to effectively lead a project in today's changing environment. People operating as a team should be the ones driving technology, not the other way around.

Despite the grim effects of the pandemic, it is possible to use the lessons learned for the benefit of society. Conclusively, a learner-centered aerospace education in U.S. educational institutions has the potential to deliver a human-centric workforce that values teamwork and leverages technologies to advance the U.S. aerospace workforce in its future efforts. ★

Amir S. Gohardani is co-founder of Springs of Dreams Corp., a nonprofit educational organization in Orange County, California. An AIAA associate fellow, he chairs the institute's Society and Aerospace Technology Outreach Committee. He has a doctorate in aerospace engineering from Cranfield University in the U.K. and a college teaching certificate in learner-centered education from the University of Arizona.

U.S. Marine Corps Staff Sgt. Jacob Osborne

APPLYING AI TO THE RIGHT NATIONAL SECURITY PROBLEMS

Leaders in the U.S. national security enterprise are intrigued by artificial intelligence. Capitalizing on this groundbreaking computing technology will require firsthand knowledge of needs and discipline in deciding which of those AI can meet. MITRE Corp.'s Eliahu "Eli" H. Niewood explains.

BY ELIAHU H. NIEWOOD

The in-development Joint All-Domain Command and Control architecture would drastically increase the volume of data the U.S. armed services would receive. Artificial intelligence could assist by identifying and sorting relevant information for particular operators.

Northop Grumman

When I was 17, I met the father of the nuclear submarine, U.S. Navy Adm. Hyman Rickover, at a science fair I was participating in. When he stopped by my booth, I didn't know who he was. He was at least six decades older than me and asking tough questions that I couldn't answer. Only after he walked away did someone tell me about my brush with one of the greatest national security innovators in history.

Rickover is a great example of someone in national security who understood both state-of-the-art technology and mission need. Steeped in the intricacies of electrical engineering and having served on two submarines in the pre-World War II era, he approached the tremendous challenge of building a nuclear reactor in a sub with extensive firsthand knowledge, all with the ultimate goal of making our nation safer.

Like nuclear power in the 1950s, artificial intelligence could be transformational. Yet, many in the U.S. national security enterprise today bemoan the slow adoption of it by the U.S. Department of Defense and the intelligence community. Many of the challenges we face with AI are common with other technology areas that the department has been slow to operationalize compared to private industry.

Innovators in the consumer space are almost always solving a problem that they've experienced themselves or, at the very least, witnessed. The people who came up with coatings to allow ketchup to flow smoothly from a bottle were not alerted to the problem through a combatant commander's integrated priority list. Rather, they probably ruined a tablecloth or two by hitting the bottom of the bottle too hard, and so they set out to solve the problem. Or consider car cupholders. I'd be willing to bet the designers of that innovation experienced the unique joy of hot coffee in their laps on a morning commute — or saw it happen to someone else.

Even in the commercial sector, where the problem space isn't as universally understood as on the consumer side, many innovations come from people who have firsthand knowledge of the problems to be addressed. From the communications experts trying to solve the problems of maintaining signal to noise over long distances to the mechanical engineers who've spent thousands of hours on the machine shop floor, many in the commercial space have deep firsthand experience they can bring to bear.

By contrast, in the national security space, we start

▲ If developers are paired with people who have firsthand knowledge of the problem, artificial intelligence could be as "transformational" as nuclear power was in the 1950s, writes MITRE's Eliahu "Eli" H. Niewood. U.S. Navy Adm. Hyman Rickover's firsthand experience with submarines helped him to better oversee development of reactors for the first nuclear-powered submarine, USS Nautilus, pictured here on the Thames River in 1954.

with significant separation between the people who have problems to solve and the people who understand and develop the technology to solve those problems. Then we increase that spacing through security classification and special access limitations — and then increase it a little more through contracting rules. It's as though we're seeking a solution to spilled coffee or an unwanted burst of ketchup by assigning someone who's never been in a car or eaten a burger to issue a request for information seeking possible solutions.

Adding to the challenge, even the very warfighters for whom we are developing weapons and information systems likely won't experience the need for them firsthand until they find themselves in a conflict. Command and control at the scale and complexity of what we will see in conflict with a peer nation probably can't be replicated fully in any environment short of that conflict. Even a full-up exercise only comes close. And the challenges and cost of mounting that exercise mean it only happens a couple of times a year at best, so there's little opportunity for experimentation.

So far, the national security enterprise has had some success at adopting commercial AI technology. The Defense Department and the intelligence community are making progress toward applying natural language processing, machine vision for electro-optical imagery and cyber monitoring of computer networks for malware and nefarious behavior. Yet the reality is that AI isn't that different from other emerging technologies that have been slow to reach their full potential in national security while doing well in consumer and commercial spaces.

The problem isn't ethical concerns around AI. Although intelligent weapons are new, we've had autonomous weapons since the first mine was set, since the first lock-on-after launch missile was fired — or for that matter, since the first camouflage was laid over a pit with spikes. And the problem isn't that we don't have data lakes with multilevel security filled with all the data in the world. AI isn't going to magically make sense of random bits of data pulled from a cloud somewhere.

The problem is, in fact, the problems people expect AI to solve.

We don't have enough people who bring together an understanding of AI with a firsthand or even secondhand knowledge of the operational problems we'd like to solve. Too many of our senior leaders and even operators have an unrealistic view of what AI can and can't do. Too many of our AI experts are naïve about the real problems. I've seen too many briefings from leaders and operators saying "and then we will use AI to do X" when X isn't feasible yet. I've worked with brilliant academics who've developed revolutionary AI capabilities, but don't understand the true complexity of combat.

Three national security problems that AI might help us solve

So, if AI can't "magically" solve every problem, the key is to identify those where it might realistically offer significant impact. From there, we can establish some lasting partnerships by matching academics and AI developers with the right clearances to warfighters and operators. We could then build modeling and simulation sandboxes where technologists can apply their AI algorithms to reasonable fidelity simulations that someone else builds for them — and that pass muster from those with firsthand experience. Following are a few examples of specific problems that are feasible to solve with AI but that the commercial sector won't solve for us alone:

1. Creating courses of action for operational command and control

The U.S. National Defense Strategy recognizes that the joint force must be able to rapidly plan and execute operations simultaneously across all warfighting domains: land, sea, air, space and cyber. So the services and the intelligence community are working together to enable Joint All-Domain Command and Control (JADC2), a new battle command architecture for multidomain operations. But many of the conversations confuse development of resilient, cross-service communications systems (which would be an enabler for JADC2) with development of the actual sense-making and decision-making needed to advance the way we do command and control. While dumping enough data into a common data lake won't allow AI to magically make sense of the world, AI is remarkably powerful at coming up with novel strategies for winning a variety of video and board games. We need to see if those same AI approaches could help us develop courses of action for operational-level decisions in conflict about how to use a set of sensors and weapons against a set of targets and tasks. Admittedly, as we try and bring capabilities from different domains and services together, the assignment problems get more complex and difficult computationally: These aren't "games" where players take turns, there may be no way to measure the instantaneous value of a move, there's no closed-form rule book to apply and the game board changes over time and from case to case. Nevertheless, I believe existing AI approaches could be adapted to help warfighters make better battlefield decisions faster than the adversary while maintaining human oversight and the commander's intent.

2. Detecting anomalies

As we collect more and more data before crisis or conflict, we may be able to use AI techniques to understand normal behavior by adversary military units and automatically alert operators if something appears different from the everyday norm. Military analysts do this today, but it can be labor intensive, lack timelines or be based on limited data. Human-machine teams may be the best choice for these applications.

3. Identifying and displaying the "right" data the right way

AI could help us understand what data or types of data different operators or different classes of operators might want to see and how that data should be presented to them. Again, if and when JADC2 becomes operational, the volume of data flowing to decision-makers is likely to grow significantly. It will be increasingly difficult for them to know what data to look at. For instance, a joint commander and maritime targeting cell operator may both need data from the same sources but otherwise have little overlap. And naturally operators will all respond differently to information displays. Perhaps automation schemes or AI could learn the preferences of individual operators or automatically configure workstations to their roles.

As with all national security innovations, when it comes to AI, we need to make the users and the mission problems they face front and center in our efforts to get emerging technology into the field. Rather than starting with the technology and bringing together technologists motivated by advancing the state of the art, we must identify the important problems that AI might realistically help us solve.

We can't all be Adm. Rickover, both a technological visionary and warfighter. But we can match academics and AI developers with the right clearances to warfighters and operators — and pitch them against the right national security problems.

That's how we can make our nation safer. ★

Eliahu "Eli" H. Niewood became MITRE Corp.'s vice president of air and space forces in July after two years as vice president of intelligence programs and cross-cutting capabilities. He holds bachelor's, master's and doctoral degrees in aeronautics and astronautics from MIT.

AIAA Bulletin

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Calendar

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2022			
15 Jun–10 Aug	Missile Design: A Comprehensive Guide to Propulsion, Aerodynamics, Weight, Flight Performance, Guidance, Lethality, System Engineering, and Development Course	ONLINE (learning.aiaa.org)	
16–24 Jul*	44th Scientific Assembly of the Committee on Space Research and Associate Events (COSPAR)	Athens, Greece (cospar-assembly.org)	11 Feb 22
19 Jul–11 Aug	Design of Electrified Propulsion Aircraft Course	ONLINE (learning.aiaa.org)	
27 Jul	AIAA Aerospace Perspectives Webinar: Space Debris Mitigation and Management, presented by The MITRE Corporation	aiaa.org/events-learning/aiaa-webinars/aerospace-perspectives-series	
7–11 Aug*	AAS/AIAA Astrodynamics Specialist Conference	Charlotte, NC (space-flight.org/docs/2022_summer/2022_summer.html)	1 Apr 22
1 Sep	2022 Section Awards Presentation	Online	
4–9 Sep*	33rd Congress of the International Council of the Aeronautical Sciences (ICAS 2022)	Stockholm, Sweden (icas2022.com)	10 Feb 22
7 Sep	ASCENDxNuclear	(www.ascend.events/ascendx)	
7–30 Sep	Electrochemical Energy Systems for Electrified Aircraft Propulsion Course	ONLINE (learning.aiaa.org)	
13–22 Sep	Aircraft Reliability & Reliability Centered Maintenance Course	ONLINE (learning.aiaa.org)	
18–22 Sep*	73rd International Astronautical Congress	Paris, France (iac2022.org)	
18–22 Sep*	Digital Avionics Systems Conference (DASC)	Portsmouth, VA (2022.dasconline.org)	
20 Sep	AIAA Professional Virtual Career Fair		
20 Sep–13 Oct	Flight Vehicle Guidance Navigation and Control Systems (GNC): Analysis and Design Course	ONLINE (learning.aiaa.org)	
27 Sep–3 Nov	Introduction to Aviation Data Science Course	ONLINE (learning.aiaa.org)	
28 Sep–21 Oct	Business Development for Aerospace Professionals Course	ONLINE (learning.aiaa.org)	
28 Sep–21 Oct	Fundamentals and Applications of Pressure Gain Combustion Course	ONLINE (learning.aiaa.org)	
4–20 Oct	Overview of Python for Engineering Program Course	ONLINE (learning.aiaa.org)	
4–27 Oct	Propeller Aerodynamics for Advanced Air Mobility: Fundamentals and Integration Effects Course	ONLINE (learning.aiaa.org)	
11–20 Oct	Higher Fidelity Designs for the Aerospace Industry w/ Fluid-Thermal Structural Interaction (FTSI) Course	ONLINE (learning.aiaa.org)	
12, 13, 14 Oct	Understanding Cybersecurity in the Space Domain Course	ONLINE (learning.aiaa.org)	
12 Oct–21 Nov	Spacecraft Design, Development, and Operations Course	ONLINE (learning.aiaa.org)	

For more information on meetings listed below, visit our website at aiaa.org/events or call 800.639.AIAA or 703.264.7500 (outside U.S.).

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2022			
18 Oct–10 Nov	Aviation Cybersecurity Course	ONLINE (learning.aiaa.org)	
24–26 Oct	ASCEND Powered by AIAA	Las Vegas, NV	7 Apr 22
1–10 Nov	Designing Better CubeSats Using System-Level Simulations Course	ONLINE (learning.aiaa.org)	
1–10 Nov	eVTOL Infrastructure Considerations for Advanced Air Mobility Course	ONLINE (learning.aiaa.org)	
7, 8, 9, 10 Nov	Space Mission Operations Course	ONLINE (learning.aiaa.org)	
17–19 Nov	Young Professionals Students and Educators (YPSE) Conference	Laurel, MD	
28–29 Nov	AIAA Region VII Student Conference	Adelaide, Australia	31 Aug 22
2023			
15–19 Jan*	33rd AAS/AIAA Space Flight Mechanics Meeting	Austin, TX (space-flight.org/docs/2023_winter/2023_winter.html)	
23–27 Jan	AIAA SciTech Forum	National Harbor, MD	1 Jun 22
4–11 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
11–13 Apr	AIAA DEFENSE Forum	Laurel, MD	18 Aug 22
12–16 Jun	AIAA AVIATION Forum	San Diego, CA	9 Nov 22
27–30 Jun*	ICNPAA 2021: Mathematical Problems in Engineering, Aerospace and Sciences	Prague, Czech Republic (icnpaa.com)	
2–6 Oct*	74th International Astronautical Congress	Baku, Azerbaijan (iac2023.org)	
23–25 Oct	ASCEND Powered by AIAA	Las Vegas, NV	

**Meetings cosponsored by AIAA. Cosponsorship forms can be found at aiaa.org/events-learning/exhibit-sponsorship/co-sponsorship-opportunities.*

AIAA Continuing Education offerings

Recognizing Top Achievements – An AIAA Tradition

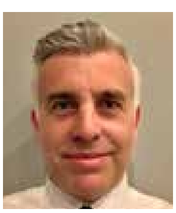
AIAA is committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. From the major missions that re-imagine how our nation utilizes air and space to the inventive new applications that enhance everyday living, aerospace professionals leverage their knowledge for the benefit of society. AIAA continues to celebrate that pioneering spirit showcasing the very best in the aerospace industry.

AIAA acknowledges the following individuals who were recognized between February and June 2022

26th Aerodynamic Decelerator Systems Technology Conference and Seminar

16–19 May 2022
Toulouse, France

2022 AIAA Theodor W. Knacke Aerodynamic Decelerator Systems Award



Benjamin A. Tutt
Airborne Systems
For a lifetime of continued excellence and leadership in the field of modeling and simulation of aerodynamic decelerators.

AIAA/CEAS Aeroacoustics Conference

14–17 June 2022
Southampton, United Kingdom

2022 AIAA Aeroacoustics Award

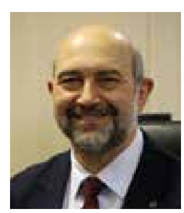
Kenneth S. Brentner
Pennsylvania State University
For fundamental contributions to aeroacoustics and rotorcraft noise prediction, including the introduction of the permeable surface formulations of the Ffowcs Williams and Hawkings equation.

AIAA AVIATION Forum

27 June–1 July 2022
Chicago, IL

SERVICE AWARDS

Sustained Service Award

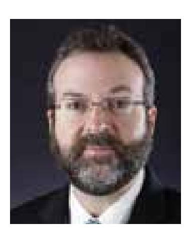


João Luiz F. Azevedo
Instituto de Aeronáutica e Espaço, Brazil
For more than 10 years of service as Deputy Director–Region VII and as a member of the AIAA Education Series Editorial Advisory Board.

2022 AIAA Sustained Service Award

Carlos E. S. Cesnik
University of Michigan
For nearly three decades of sustained and meritorious service to AIAA in a variety of leadership roles within its technical activities.

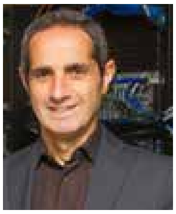
2022 AIAA Sustained Service Award



John R. Chawner
Cadence Design Systems, Inc.
For over 40 years of continuous involvement and advocacy to drive CFD engagement and advancements in AIAA through workshops and technical and integration committees.

THANK YOU to all the nominators and supporters of these award winners.

2022 AIAA Sustained Service Award



Farzad Mashayek
University of Illinois Chicago
For outstanding, sustained contributions to the Institute at the section and regional levels and to national technical committees with role-model activities in terrestrial energy generation and storage.

TECHNICAL AWARDS

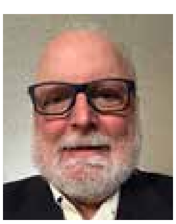
2021 Elmer A. Sperry Award

Michimasa Fujino
HondaJet
In recognition of his singular achievement of research and development of new technologies for business aviation including the Over-the-Wing Engine Mount and Natural Laminar Flow airfoil, and the introduction to the market of commercial aircraft based on these technologies through the formation of HondaJet.

2022 AIAA Aerodynamics Award

Marilyn J. Smith
Georgia Institute of Technology
For contributions to the computational and theoretical aerodynamic analysis of static and dynamic systems with separated flows, particularly for vertical takeoff and landing rotorcraft vehicles.

2022 AIAA Aircraft Design Award

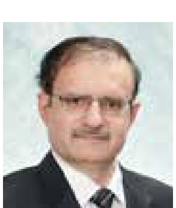


Steve Ericson
Overair
For a lifetime of innovative aircraft designs and exceptional skills in configuration design, as well as mentoring young engineers in aircraft design.

2022 AIAA Chanute Flight Test Award

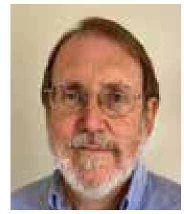
Rogers E. Smith
Consultant/SDI
For career-long achievements and contributions to the safe practices and teaching of flight testing, particularly in-flight controls and flying qualities, and significant collaboration with a diverse set of aerospace stakeholders.

2022 AIAA Fluid Dynamics Award



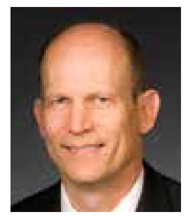
Mujeeb R. Malik
NASA Langley Research Center
For numerous and significant contributions to the understanding and control of laminar turbulent boundary-layer transition, and for exceptional leadership, particularly in the area of certification-by-analysis.

2022 AIAA Ground Testing Award



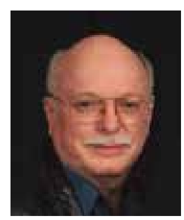
James C. Ross
NASA Ames Research Center
In recognition of decades of exemplary service and leadership in ground testing, advancing critical technologies including heavy vehicles, military aircraft, and NASA's Multipurpose Crew Vehicle Program.

2022 AIAA Hap Arnold Award for Excellence in Aeronautical Program Management



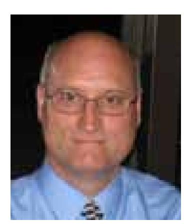
Paul W. Niewald
The Boeing Company
For championing the use of innovative tools such as digital engineering to transform aircraft development, saving time and cost while enhancing performance and safety.

2022 AIAA James A. Van Allen Space Environments Award



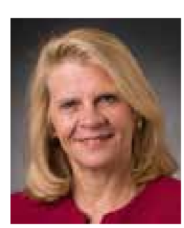
Henry B. Garrett
Jet Propulsion Laboratory, California Institute of Technology
For a lifetime of contributions to the understanding of the interactions of spacecraft with the Earth's magnetosphere and those of other planets.

2022 AIAA Losey Atmospheric Sciences Award



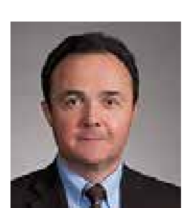
Fred H. Proctor
NASA (retired)
For leading fundamental research to characterize atmospheric-related aviation hazards and to develop advanced sensor algorithms for identifying and mitigating these hazards.

2022 AIAA Thermophysics Award



Karen A. Thole
Pennsylvania State University, START Lab
For pioneering research at the intersection of additive manufacturing and heat transfer in gas turbine engines that enables innovative combustor and turbine cooling designs.

2022 AIAA Plasmadynamics and Lasers Award



Sergey O. Macheret
Purdue University
For pioneering work on novel plasma generation and control methods and on aerospace applications of plasmas.

AIAA and Its Partner Organizations Help Students Reach for the Sky

AIAA "Look Up!" Award at Regeneron ISEF

From 8 to 13 May, 1,750 young scientists, engineers, entrepreneurs, and inventors convened both in person and virtually for a week of connecting with their peers and global STEM leaders, events, and $8 million in awards, prizes, and scholarships. It was the first time since 2019 that Regeneron International Science and Engineering Fair (ISEF) finalists had the opportunity to gather in person, and a hybrid format was offered as well. Presented at ISEF, the AIAA "Look Up!" Award celebrates exceptional high school-level research to encourage further study in aerospace.

Winners of the AIAA "Look Up!" Award receive a cash award and AIAA student membership with access to all student programs and upcoming partnership competitions and challenges. We congratulate the 2022 winners and encourage students to Look Up! and see their future in aerospace.

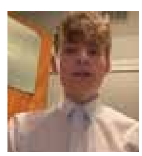
First Place ($2,000)

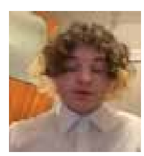
Kevin Shen, Freshman, *Olympia High School, Olympia, WA (Virtual)*
ETSD045—"A Novel Approach to Biomimicking the Avian Tail on Fixed Wing Micro Air Vehicles" (https://projectboard.world/isef/project/85289)

Second Place ($1,500)

Jue Wang, Junior, *Milton Academy, Milton, MA (Virtual)*
ETSD049—"Design and Fabrication of a Flapping-Wing Robot Based on Slider-Crank Mechanism" (https://projectboard.world/isef/project/85869)

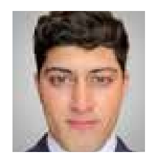
Third Place ($1,000)





Joey Gorman, Senior, and Jonathan Gutknecht, Senior, *Gwinnett School of Mathematics, Science, and Technology, Lawrenceville, GA (In person)*
ETSD012T—"Small Satellite and Launch Vehicle for Climate Change Research" (https://projectboard.world/isef/project/82750)

Fourth Place ($500)



Ravin Joshi, Senior, *Academies of Loudoun, Leesburg, VA (In person)*
ETSD033—"Constructing a Reusable Solid-Fuel Rocket Capable of Propulsive Landing" https://projectboard.world/isef/project/85280

Honorable Mention

Guan-Yu Chen and Yu-Sheng Wang, *Taipei Municipal Jianguo High School, Taipei City, Taiwan (Virtual)*
ETSD035T — Performance Enhancement of PMMA/GOx Hybrid Rocket Engine Using Swirling Injection

Team AstraCell

Conrad Challenge

The Conrad Challenge is an annual, multi-phase innovation and entrepreneurship competition that encourages young adults to participate in designing the future. Each year, teams of 2–5 students, ages 13–18, from around the world create products and/or services to address some of the most pressing global and local challenges. They become entrepreneurial problem-solvers, addressing challenging social, scientific, and societal issues through utilizing their creativity and critical-thinking skills. This year the 2022 Innovation Summit took place 26–29 April at Space Center Houston and NASA Johnson Space Center and featured 50 student teams from around the world who competed for the top honor: the Pete Conrad Scholar award.

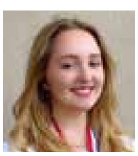
Team AstraCell, from Lambert High School, Suwanee, GA, won the Aerospace & Aviation Pete Conrad Scholar award for their presentation of an innovative alternation fuel cell technology that alleviates traditional fuels safety and durability concerns, while optimizing cost and efficiency. The CEO of Team AstraCell, **Varnica Basavaraj**, was awarded the $2,500 AIAA Scholarship Award. Varnica stated, "Sustainability has always been an area of interest for me, and I hope to take my research from AstraCell which focused on greener fuel potential along with the generous grant from the AIAA and put it toward developing this pursuit."

MAKING AN
IMPACT

AIAA Announces First Recipients of AIAA Lockheed Martin Marillyn Hewson Scholarship

AIAA announces the first recipients of the new AIAA Lockheed Martin Marillyn Hewson Scholarship. **The two $10,000 scholarships have been awarded to:**

HIGH SCHOOL WINNER: Julianna Schneider, Admitted to the Massachusetts Institute of Technology



Julianna is a U.S. Presidential Scholar, National Merit Scholar, Congressional App Challenge Winner, and FTC Dean's List Finalist. She led three FIRST robotics teams to win state, regional, and international awards and a team of NASA interns to publish research with the American Geophysical Union. Julianna created VoluntYOU, an award-winning, 501(c)(3)-backed digital platform that connects 500+ users to volunteering opportunities globally. She mentors with NASA summer programs, Science Olympiad, and FIRST robotics programs. She conducts research on improving human-robot collaboration using a pipeline of machine learning models. Julianna is an incoming freshman at MIT and will major in AI & Decision Making. She aspires to earn a graduate degree and develop novel AI architectures that improve autonomous navigation systems throughout her career as an AI engineer.

UNIVERSITY WINNER: Penélope Nieves-Colon, University of Puerto Rico, Mayaguez Campus

Penélope Nieves-Colon is a rising junior majoring in Mechanical Engineering at the University of Puerto Rico, Mayaguez Campus. Her plan is to continue studying after graduating with her bachelor's, to obtain a Ph.D. in Aerospace Engineering, with a minor in Astronautics. Having an immense interest in outer space from an early age, she plans to pursue a career in the aerospace industry, working with the development of rocketry technologies and space travel.

The AIAA Lockheed Martin Marillyn Hewson Scholarship was created in 2022 to encourage young women to study aerospace engineering and pursue a career in the aerospace defense industry. The scholarship is named for Marillyn Hewson, former chairman, president, and chief executive officer of Lockheed Martin Corporation. She joined Lockheed Martin in 1983 as an industrial engineer. During her career she held leadership positions across the corporation, including president and chief operating officer; executive vice president of Lockheed Martin's Electronic Systems business area; president of Lockheed Martin Systems Integration; executive vice president of Global Sustainment for Lockheed Martin Aeronautics.

Basil Hassan, chair of the AIAA Foundation, stated, "The AIAA Foundation is thrilled to help identify, mentor, and promote promising young aerospace talent through the AIAA Lockheed Martin Marillyn Hewson Scholarship. This new award is the first needs-based scholarship AIAA has offered, as a powerful investment in the journey of students from classroom to career. We recognize the generosity of our members and partners who help AIAA inspire as many students and educators as we can reach."

Applications for the 2023 AIAA Lockheed Martin Marillyn Hewson Scholarship will open 1 October (aiaa.org/scholarships). AIAA again will award up to two $10,000 scholarships to one high school senior female and one undergraduate female with financial need who enroll in an accredited college or university and intend to pursue an aerospace or STEM major. Applicants must demonstrate interest in a career in the aerospace defense sector. Students from groups currently underrepresented in the aerospace profession are especially encouraged to apply. For more information, email K-12STEM@aiaa.org.

CALLING ALL EDUCATORS:

Apply for the AIAA Foundation Classroom Grant

The AIAA Foundation believes that educating and inspiring the next generation of aerospace professionals is one of the most important investments we can make. The classroom grant program aims to bridge the gap in STEM funding by awarding over 80 AIAA Educator Associate members with up to $500 for STEAM projects with an emphasis on aerospace.

The application is easy to complete: explain the project, itemize the list of materials needed, and submit! Grant rules and application can be found at: aiaa.org/get-involved/students-educators/aiaa-foundation-classroom-grant-program.

APPLICATION CLOSES 30 SEPTEMBER 2022. *Sponsored by The Boeing Company.*

SAT OC – Impactful Effects

By Amir S. Gohardani, SAT OC Chair

The AIAA Society and Aerospace Technology Outreach Committee (SAT OC) recently reconfirmed its mission to promote the transfer and use of aerospace technology for the benefit of society. A variety of topics with impactful effects made it to the discussion plane, including astrosociology.

Astrosociology is a multidisciplinary academic field that includes the social/behavioral sciences (e.g., sociology, anthropology, psychology, political science, economics, archeology), humanities, and arts. Astrosociology unites non-STEM fields with space-related issues so scientists can better collaborate. This is a similar approach to that of astrobiology. Jim Pass, lead contact for astrosociology at SAT OC, has shaped astrosociology for many years. Interested parties are encouraged to contact SAT OC if they are interested in this multidisciplinary academic field.

SAT OC Spotlight

Chi Mai recently celebrated 13 years of membership with SAT OC.

In this issue, the SAT OC highlights Chi Mai, a member of the AIAA SAT OC since 2009. Chi is a senior aerospace engineer at the U.S. Government Accountability Office (GAO) on its Science, Technology Assessment, and Analytics team. He leads project teams to analyze recent science and technology developments, highlight potential effects of technological change, and make science and technology concepts readily accessible to policymakers and the public. Chi's recent work involves satellite constellations and positioning, navigation, and timing alternatives to the GPS. He also supports GAO's work in advanced air mobility, sustainable aviation fuels, hypersonic weapons, and defense capabilities.

At GAO Chi looks at emerging technologies and how they influence and are affected by social, legal, economic, and national security factors. This aligns with SAT OC's focus areas of: 1) how aerospace technology and techniques help solve critical societal challenges and improve quality of life and 2) the interactions of the aerospace enterprise with broader social and cultural trends.

Prior to GAO, Chi was a research aerospace engineer for the Air Force Research Laboratory's Munitions Directorate at Eglin Air Force Base. He conducted and supported wind-tunnel tests for commercial and government missile technology development programs. He also directed a series of small-scale experiments and managed a research portfolio for air blast. Chi received degrees in aerospace engineering from Texas A&M University. For his graduate studies, he received the Department of Defense Science, Mathematics, and Research for Transformation (DOD SMART) scholarship.

Chi serves on the advisory council for the AIAA North Texas Section. He also served as an officer for the AIAA Northwest Florida Section for several years, including as section chair (2017–2019), when the section was awarded Outstanding Section for 2018-2019 in the small section category. Chi also serves as an industry advisory board member for the Department of Aerospace Engineering at Embry-Riddle Aeronautical University–Daytona Beach. SAT OC takes pride in the success of its membership and celebrates individuals such as Chi for their skillsets, dedication, motivation, and drive to create a brighter future in a better society.

Diversity Corner

Yanping Guo, Class of 2022 AIAA Fellow.

IMAGE: JOHN HOPKINS UNIVERSITY APL

NAME: Dr. Yanping Guo

NOTABLE CONTRIBUTIONS:
Dr. Guo is a space mission designer and member of the Principal Professional Staff of the Johns Hopkins University Applied Physics Laboratory (APL). Dr. Guo has a long list of interplanetary mission design accomplishments as a developer and leader for several NASA mission proposals, studies, and flight projects. She has received numerous awards from many professional organizations, including the NASA Silver Achievement Medal. In 2004, the International Astronomical Union approved the name "Guo" for asteroid 28513 to celebrate her many contributions to the space and mission design field. She is an inspiration to the aerospace community and during AAPI Heritage she was recognized by AIAA for her achievements.

POTENTIAL SOCIETAL IMPACT OF CONTRIBUTIONS:
Dr. Guo was highly influential in turning the much-studied but never realized Solar Probe into a doable mission, Parker Solar Probe. Using Venus instead of Jupiter for gravity assists, she enabled 24 solar flybys instead of only one, thus multiplying the science value while decreasing the complexity and cost of the mission. Dr. Guo is responsible for the mission design of NASA's APL-built New Horizons spacecraft from the initial proposal through its successful operations. New Horizons performed a flyby of Pluto in 2015 and the first flyby of a Kuiper Belt object in 2019 and is now on an extended mission to explore the vast Kuiper Belt region.

In collaboration with the AIAA Diversity and Inclusion Working Group and Claudine Phaire, SAT OC is highlighting prominent members of the wider aerospace community in the Diversity Corner.

AIAA Awards Special Service Citations to Members

The AIAA Regional Engagement Activities Division (READ) recognized members for their contributions for recent activities.

University of California at Merced students Nathan Ibarra, Ethan Murcia, and Matthew Vezien were honored for their leadership and incredible service to the 2022 AIAA Region VI Student Conference in April.

Basile Perin was recognized for planning, hosting, and executing the 26th AIAA Aerodynamic, Decelerator Systems Technology Conference and Seminar.

Matthew Tufts was recognized for his outstanding service as chair for the 2022 AIAA Dayton/Cincinnati Section's Dayton/Cincinnati Aerospace Sciences Symposium, which took place in March.

IMPORTANT ANNOUNCEMENT

New Editor-in-Chief Sought for the *Journal of Air Transportation*

Karl Bilimoria, editor-in-chief of the *Journal of Air Transportation (JAT)*, has announced his intention to retire from the journal at the end of 2022. The AIAA Publications Committee is conducting a formal search for a new editor-in-chief of JAT and is looking for a diverse pool of highly qualified candidates. This position is open to all and we encourage applications from the underrepresented demographics of the aerospace community.

The selection process for the new editor-in-chief will be objective and based on the merits of the candidates as well as the long-term development and welfare of the journal. JAT is devoted to the dissemination of original archival papers describing new developments in air traffic management and aviation operations of all flight vehicles, including unmanned aerial vehicles (UAVs) and space vehicles, operating in the global airspace system. The scope of the journal includes theory, applications, technologies, operations, economics, and policy. Also included are aviation-specific aspects of some broader subjects: communications, navigation, and surveillance (CNS); operations research; systems engineering and complexity; system safety and resilience; human factors; decision support tools; human-machine interaction; and automation/autonomy.

More information about JAT can be found on Aerospace Research Central.

Candidate applications and questions about the selection process and requirements can be directed to Michele Dominiak, AIAA Managing Director, Publications. Résumés, two recent letters of recommendation, and a statement of interest to serve will be needed from all applicants. An initial deadline of 31 August 2022 has been set, but applications will continue to be accepted until the position is filled. The search announcement can be found on Aerospace Research Central.

IMPORTANT ANNOUNCEMENT

New Editor-in-Chief Sought for the *Journal of Aircraft*

Eli Livne, editor-in-chief of the *Journal of Aircraft (JA)*, has announced his intention to retire from the journal at the end of 2022. The AIAA Publications Committee is conducting a formal search for a new editor-in-chief of JA and is looking for a diverse pool of highly qualified candidates. This position is open to all and we encourage applications from the underrepresented demographics of the aerospace community.

The selection process for the new editor-in-chief will be objective and based on the merits of the candidates as well as the long-term development and welfare of the journal. JA is devoted to the advancement of the applied science and technology of airborne flight through the dissemination of original archival papers describing significant advances in aircraft, the operation of aircraft, and applications of aircraft technology to other fields. The journal publishes qualified papers on aircraft systems, air transportation, air traffic management, and multidisciplinary design optimization of aircraft, flight mechanics, flight and ground testing, applied computational fluid dynamics, flight safety, weather and noise hazards, human factors, airport design, airline operations, application of computers to aircraft including artificial intelligence/ expert systems, production methods, engineering economic analyses, affordability, reliability, maintainability, and logistics support, integration of propulsion and control systems into aircraft design and operations, aircraft aerodynamics (including unsteady aerodynamics), structural design/dynamics , aeroelasticity, and aeroacoustics. It publishes papers on general aviation, military and civilian aircraft, UAV, STOL and V/ STOL, subsonic, supersonic, transonic, and hypersonic aircraft.

More information about JA can be found on Aerospace Research Central.

Candidate applications and questions about the selection process and requirements can be directed to Michele Dominiak, AIAA Managing Director, Publications. Résumés, two recent letters of recommendation, and a statement of interest to serve will be needed from all applicants. An initial deadline of 31 August 2022 has been set, but applications will continue to be accepted until the position is filled. The search announcement can be found on Aerospace Research Central.

Obituaries

AIAA Fellow Koff Died in November 2021

Bernard L. Koff, 94, died on 2 November 2021.

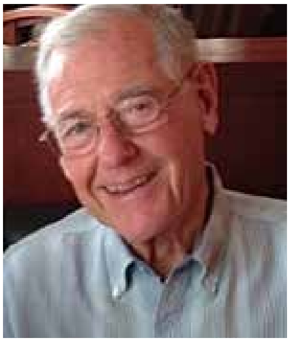
Koff received a B.S. degree in Mechanical Engineering from Clarkson University, an M.S. degree in Mechanical Engineering from New York State University, and an Honorary Doctor of Science from Clarkson University.

He was a pioneer in the gas turbine industry for 60 years and his leadership produced innovative breakthroughs in design and development. Koff worked for both General Electric and Pratt & Whitney, from which he retired as executive vice president of Engineering and Technology. His contributions impacted the design and development of over half of all jet engines flying. His patents and highly regarded technical papers cover the entire spectrum of jet engine design and manufacturing technology.

Koff was honored with many of the premier awards in the industry, including the 1992 Daniel Guggenheim Medal, Air Force Association Theodore von Karman Award, 1990 AIAA Reed Aeronautics Award, 1984 AIAA Air Breathing Propulsion Award, 1989 AIAA Engineer of the Year, AIAA & SAE Littlewood Lecture Award, ASME Tom Sawyer Award, SAE Franklin Kolk Award, SAE Garrett Turbomachinery Award, the GE Perry Egbert Award, and the P&W George Mead Medal.

Koff was a Fellow and Honorary Member of ASME, Fellow of both AIAA and SAE, and a member of the National Academy of Engineering.

AIAA Fellow Smith Died in February



Anthony Mactier "Mac" Smith passed away at the age of 90 on 20 February.

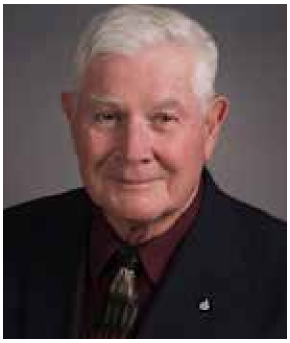
Smith graduated from Johns Hopkins University with a Mechanical Engineering degree in 1953 and served in the Army Corp of Engineers after receiving a commission via Army ROTC. He went on to earn an M.S. in Mechanical Engineering from Drexel University and embarked on a 60+-year engineering career.

He received international recognition for his pioneering efforts in the application of reliability-centered maintenance (RCM) to complex systems and facilities in the industrial and government areas. Smith spent 24 years with General Electric gaining technical and management experience. For over 23 years, he concentrated on providing RCM consulting and education services to many of the Fortune 100 companies, as well as to the U.S. Air Force, U.S. Navy, and NASA, helping many different industries improve their performance and safety via RCM.

Over the course of his career Smith published more than 50 technical papers. He also was the author of two books: *Reliability-Centered Maintenance* (McGraw-Hill School Education Group 1993) and *RCM—Gateway to World Class Maintenance* (coauthored with Glenn R. Hinchcliffe, Elsevier Science & Technology, 2003). His work spans projects in energy, aerospace, and high-volume manufacturing sectors. He was also involved in leading the team that developed the re-entry system for astronauts returning from the moon.

An AIAA Fellow, Smith was awarded the AIAA Systems Effectiveness and Safety Award in 1975.

AIAA Fellow Nicolai Died in May



Leland M. Nicolai died on 3 May. He was 86 years old.

Nicolai received his B.S. in Aerospace Engineering from the University of Washington in 1957, before joining the U.S. Air Force. He received his M.S. (1962) and Ph.D. (1968) in Aerospace Engineering from the University of Oklahoma and the University of Michigan, respectively. He also attended Auburn University where he received an MBA in 1976.

Nicolai served for 23 years in the U.S. Air Force as an R&D officer and instructor at the U.S. Air Force Academy. Before retiring from the U.S. Air Force as a Colonel in 1981, he received an Air War College Certificate while at Maxwell AFB.

After leaving the U.S. Air Force, Nicolai became manager of Flight Sciences at Northrop Grumman Aircraft. In 1984, he became vice president of engineering at Fairchild Republic before going to work for Lockheed Martin in 1986, where he was director of advanced design.

At Lockheed Nicolai was chief executive of the AGM-158 JASSAM (Joint Air-to-Surface Standoff Missile) program from 1995 to 2002. Among his achievements in the field of aerospace engineering, Nicolai designed and developed the DARPA low-signature, nuclear-armed Advanced Cruise Missile. He also designed the 500 lb. unmanned AFFDL X-56 flutter research vehicle to explore high aspect ratio HALE flight technologies.

A Lockheed Martin Fellow (2002–2013), Nicolai also was recognized for his achievements with the 2011 AIAA Aircraft Design Award, the SAE Kelly Johnson Aircraft Design Award, the S. Cal. Engineering Council Kelly Johnson Aircraft Design Award, NATO/AGARD Outstanding Service Award, LM Aero Presidents Award, and Lockheed Martin Skunk Works Golden Skunk Award.

He was the author of several textbooks on aircraft design, including the Fundamentals of Aircraft Design (AIAA, 1975) and Lessons Learned: A Guide to Improved Aircraft Design (AIAA, 2016). He co-authored with Grant E. Carichner Fundamentals of Aircraft and Airship Design, Volume 1 — Aircraft Design (AIAA, 2010) and Fundamentals of Aircraft and Airship Design, Volume 2 – Airship Design and Case Studies (AIAA, 2013), and in 2018, they won the Summerfield Book Award for the books. Nicolai also served AIAA as a member of the Lighter-than-Air Systems Technical Committee (1989–1994) and the Committee on Higher Education (1989–1996).

AIAA Fellow Brown Died in May

Alan C. Brown died on 25 May. He was 92 years old.

Born in England, Brown apprenticed at Blackburn Aircraft in England (1945–1950), and received aeronautical engineering diplomas from Hull Technical College (1950) and the College of Aeronautics at Cranfield Institute of Technology (1952). He then worked at Bristol Aeroplane Company as an aerodynamicist.

Emigrating to the United States in 1956, he worked as a research associate and lecturer at the University of Southern California and a research associate at Wiancko Engineering Company before joining Lockheed in 1960, starting in the physics laboratory of the Lockheed Missiles and Space Company.

In the mid-1960s, Brown worked on the Supersonic Transport and the FX and VSX aircraft. He also was engineering manager for the Lockheed group at Rolls-Royce on the L-1011 commercial transport program. In 1969, he earned his M.S. in aeronautical engineering from Stanford University. Brown was a member of the Lockheed Advanced Development Projects (Skunk Works) from 1975 to 1989. After serving as the deputy program manager for the Have Blue low-observable research aircraft, he was program manager and chief engineer for the F-117A Stealth Fighter and director of Low Observable Technology.

Brown retired in 1992 as director of engineering at Lockheed Corporate Headquarters, where his two principal concerns were the promulgation of concurrent engineering and stealth technology throughout the corporation. He has given invited papers on both these subjects at national and international levels. After his retirement from Lockheed, Brown taught short courses at Cranfield University (England), Linkoping University (Sweden), Georgia Institute of Technology, and the Naval Postgraduate School. In addition, he was active in the University of California Mathematics, Engineering, and Science Achievement (MESA) program for middle and high schools (1994–2010), serving on the state committee and working particularly with Watsonville High School.

Brown was a Fellow of AIAA and the Royal Aeronautical Society, and a member of the National Academy of Engineering. He received prestigious awards, including the 1990 Aircraft Design Award, 2020 AIAA Reed Award, the J.C. Hunsaker Award, and the 2021 Daniel Guggenheim Medal for his engineering innovation and leadership.

JAHNIVERSE

CONTINUED FROM PAGE 64

I went to China in 2019 at the invitation of the Chinese Academy of Sciences to teach a short course on orbit determination, the students who attended knew my published research, the entirety of it, more than my own research team and students back home. The questions I was asked were nuanced and insightful. The Chinese are awake and thriving in many ways. They have their own space station and have landed robotic spacecraft on the moon and also Mars — incredible feats by any measure. We should not be surprised that they are good at hypersonics too.

As a former spacecraft navigator for NASA's Jet Propulsion Laboratory, I can attest that you don't get things on the Martian surface in working order by luck, chance or copying others. You only achieve this level of success by really knowing what you're doing. Additionally, as a co-editor of the peer-reviewed journal Acta Astronautica, I've seen the quality of papers being submitted from China over the years. While they might have been lackluster a decade ago, they're now among the very best papers I've ever seen.

If the U.S. does not treat China, and other countries for that matter, as our equals at a roundtable, seek to understand their cultural nuances and accept the evidence of their scientific and technological prowess, we will be on a sure path to experience technological surprise at their hands at the time and place of their choosing.

We also need to be more transparent about our own capabilities, meaning the products of our increased R&D in hypersonics and other fields. The best conflict is the one avoided, and the maximum appropriate level of technological transparency is the best way to deter conflict. Then-U.S. Air Force Gen. John Hyten, during his tenure as vice chairman of the Joint Chiefs of Staff, said it best when speaking with reporters before his retirement last year: "You actually can't deter your adversary if everything you have is in the black. The last element of deterrence that we don't do is communicate it credibly to our adversaries. Communication is talking. Communication is demonstrating capability."

Being overly secretive might be the very thing that makes an adversary believe that they could be successful over us. If we can communicate and demonstrate our capabilities in a limited way to those who want to spread conflict and violence, we have an opportunity to deter them from doing so because the potential consequences will be real and verifiable.

To be sure, there are those who have the intent, opportunity and technological capability to cause the U.S. harm, and we must have the ability to overcome and withstand any threat possible. Implementing this two-pronged strategy of not underestimating an adversary and being as transparent as possible will make surprises rare and maximize deterrence.

Humanity will be the better for it. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1922

1 **July 1** The U.S. Congress approves plans to convert the battlecruisers USS Lexington and USS Saratoga into aircraft carriers, as part of the agreements resulting from the Washington Naval Conference. These two 36,000-metric-ton carriers become the backbone of U.S. naval aviation in the interwar years and play key roles during World War II. David Baker, **Flight and Flying: A Chronology**, p. 144.

July 29 The first of 200 Thomas-Morse MB-3A biplane fighters is delivered to the U.S. Army Air Service. Because of the peculiarity of the Army's procurement system, Boeing won the bid to manufacture the aircraft using the design creating by Thomas-Morse. David Baker, **Flight and Flying: A Chronology,** p. 144.

1947

July 3 The U.S. Army Air Force launches a 10-balloon cluster with upper atmospheric instruments provided by New York University from Holloman Air Field in New Mexico. The cluster reaches an altitude of 5,600 meters. E. Emme, **Aeronautics and Astronautics 1915-60**, p. 57.

2 **July 8** The Boeing 377 Stratocruiser makes its inaugural flight. This civilian version of the C-97 military transporter has a double-deck fuselage that allows for a small passenger lounge in addition to regular passenger accommodations. Pan American Airways becomes the largest user, ordering 29 of the long-distance carriers. **The Aeroplane**, Sept. 5, 1947, p. 275; R.E.G. Davies, **Airlines of the United States Since 1914**, p. 379.

July 9 The U.S. Navy's ramjet-powered Gorgon IV test missile makes a 28-minute flight at the Naval Air Test Center in California. The Gorgon is made by the Glenn L. Martin Co. E. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 57.

July 16 The world's first turbojet flying boat, the Saunders-Roe SR.A/1, reaches 805 kph during its first flight. The experimental single-seat fighter is powered by two Metropolitan-Vickers F.2 axial-flow jet engines. F. Mason and M. Windrow, **Know Aviation**, p. 53; **The Aeroplane**, Aug. 8, 1947, p. 148.

July 24 The Soviet Union test flies its first jet-powered bomber, the Ilyushin Il-22, although the design is unsuccessful and the plane is canceled after the test flights. Vaclav Nemecek, **The History of Soviet Aircraft Since 1918,** pp. 170-171.

July 27 The Tupolev Tu-12 makes a successful test flight and becomes the Soviet Union's first jet-powered bomber to enter production. Vaclav Nemecek, **The History of Soviet Aircraft Since 1918**, p. 170

1972

July 1 The Swiss Transport Museum in Lucerne inaugurates its Air and Space Wing with ceremonies attended by NASA Administrator James Fletcher, Apollo 11 astronaut Neil Armstrong and astronaut John Glenn. NASA, **Astronautics and Aeronautics, 1972,** p. 247.

July 10 NASA's Mariner 9 probe completes photomapping the entire surface of Mars, bringing the total photo count to more than 7,000. Another milestone will be reached July 20, when the spacecraft makes its 500th revolution around the planet. **NASA Release** 72-143.

July 10 This date marks the 10th anniversary of the launch of the first transoceanic TV broadcast via Telstar 1, built by Bell Telephone Laboratories for the American Telephone & Telegraph Co. Millions of viewers watched taped pictures of the American flag that the satellite transmitted from Andover, Maine, to Holmdel, New Jersey. Within a week of the 1962 demonstration, the first TV pictures from Europe and the first pictures in color were transmitted, followed within a month by the first international exchange of live TV. **NASA Special Release**, 7/4/72.

July 10 Soviet Union newspaper Izvestia reports that Soviet scientists have obtained spectrograms of the stars Vega and Agena using the Orion astronomical system on the Salyut 1 space station. The temperature of Vega is recorded as 10,000 degrees Celsius, and Agena's as 24,000 degrees Celsius. NASA, **Astronautics and Aeronautics, 1972**, p. 255.

3 **July 12** During a five-day visit to Poland, U.S. Presidential Science Adviser Edward E. David Jr. informs the Polish government that the U.S. will name the Orbiting Astronomical Observatory-3 after Polish astronomer Nicolas Copernicus, in honor of the 500th anniversary of his birth. Renamed shortly after its launch in August, the Copernicus spacecraft carries an 81-centimeter reflecting ultraviolet telescope developed by Princeton University and a smaller X-ray telescope developed by University College London to study UV and X-ray emissions of celestial bodies. NASA, **Astronautics and Aeronautics, 1972**, p. 257.

July 15 NASA's Pioneer 10 Jupiter probe enters the asteroid belt, beginning its reconnaissance of the huge region of dust and rocks that circles the sun between the orbits of Mars and Jupiter. The doughnut-shaped belt is 3 billion kilometers around, 280 million km wide and 80 million km thick, with asteroids ranging in size from dust particles to rock chunks as large as Alaska. **NASA Release** 72-136.

July 15 The U.S. Army's Sprint antiballistic missile intercepts a dummy warhead among several warheads over the Pacific Ocean. The maneuver, the 29th test of the service's Safeguard system, verified the missile's radar could lock onto a single target for interception. NASA, **Astronautics and Aeronautics, 1972**, p. 260.

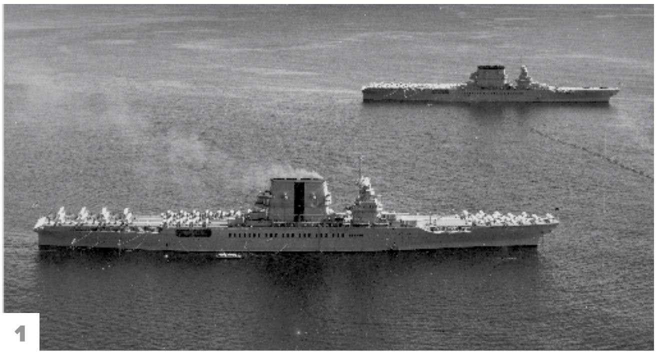
July 18 In a Washington, D.C., ceremony, Air Force Chief of Staff Gen. John Ryan awards the 1971 Mackay Trophy to Lt. Col. Thomas Estes and Lt. Col. Dewain Vick for their record-breaking 24,000-kilometer nonstop flight at speeds over Mach 3 in a Lockheed SR-71 aircraft. **National Aeronautic Association News**, August 1972, p. 1.

4 **July 18** U.S. Patent No. 3,677,502 is issued to Soviet Union aircraft designer Aleksey Tupolev and seven associates for the Tu-144 Soviet supersonic passenger aircraft. Tupolev had carried on the work of his father, Andrey Tupolev, on the aircraft. Earlier applications had been filed for Soviet patents. **New York Times**, July 22, 1972, pp. 72, 33.

July 20 NASA and the National Science Teachers Association jointly announce their approval of experiments proposed by 19 high school students from 16 states for the Skylab space station. Twenty-five experiments were selected from 3,400 proposals, but six of the experiments will not launch because of schedule constraints. **NASA Release** 72-146.

July 21 The U.S. Senate approves a resolution to return Cape Kennedy to its original name of Cape Canaveral. NASA, **Astronautics and Aeronautics, 1972**, p. 266.

July 22 The Soviet Union's Venera 8 spacecraft reaches the atmosphere of Venus after a 117-day flight spanning 483 million kilometers. The descent module separates from the spacecraft and makes a soft landing under parachutes, becoming the second Soviet spacecraft to land on Venus. Venera 8 studies Venus' atmosphere and surface layer for 50 minutes and 11 seconds before failing due to the harsh surface conditions, like its predecessor Venura 7. The probe confirms earlier data on Venus' high surface temperature of 470 degrees Celsius and pressure of 90 atmospheres. NASA, **Astronautics and Aeronautics, 1972**, p. 267.



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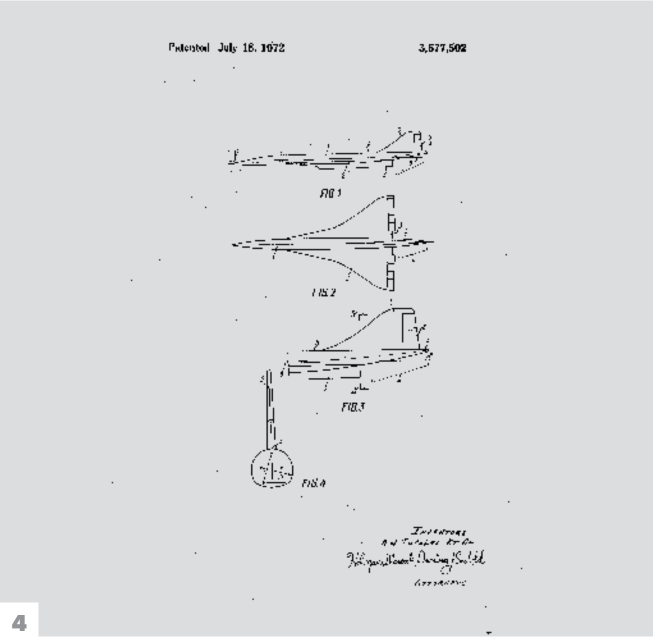

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1997

July 1 The first test flight of the modified two-seat Sukhoi Su-30MK1 fighter for the Indian Air Force is conducted at Russia's Zhukovsky Flight Test Center near Moscow. India has been negotiating for as many as 200 fighters, but the first ones already ordered do not have the thrust vectoring capabilities of the planes that will be delivered later. **Aviation Week**, April 14, 1997.

5 **July 1** Space shuttle Columbia launches from NASA's Kennedy Space Center on STS-94. The seven astronauts aboard are the same crew from STS-83, which was cut short because one of the fuel cell substacks was not producing enough electricity. NASA, **Astronautics and Aeronautics: A Chronology, 1996-2000**, p. 79.

6 **July 4** NASA's Mars Pathfinder lander touches down in the Ares Vallis region of Mars. On July 6, the 10.6-kilogram, solar-powered Sojourner rover rolls down the lander's ramp on its six wheels and begins to explore. The lander sends back 2.3 billion bits of data during its three-month life, and Sojourner takes 550 images and makes 20 chemical analyses. **Aviation Week**, July 14, 1997, pp. 26-32, 34-35; **NASA Press Releases**.

July 7 NASA's remotely piloted, solar-powered Pathfinder aircraft sets an altitude record, reaching an altitude of 71,530 feet over the U.S. Navy's Pacific Missile range off of Kauai, Hawaii. NASA, **Astronautics and Aeronautics: A Chronology, 1996-2000**, p. 80.

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1922

Aug. 6-20 The first international gliding meeting, the First Experimental Congress for Motorless Flight, is held at Puy de Combergrasse in France, with prizes amounting 100,000 francs. **Flight**, May 11, 1922, p. 273.

Aug. 12 Henri Biard wins the Schneider Trophy race held off the coast off Naples, Italy, reaching a speed of 237 kph in a Supermarine Sea Lion II flying boat. The aircraft was designed by Reginald Mitchell, who would go on to design the Supermarine Spitfire and S.6B race plane. David Baker, **Flight and Flying: A Chronology**, p. 144.

Aug. 18 German pilot Arthur Martens achieves the first gliding flight of more than an hour. Charles H. Gibbs-Smith, **Aviation**, p. 248.

Aug. 21 Lawrence Sperry demonstrates landing skids for airplanes at Farmingdale, Long Island, when his plane drops the regular landing wheels in flight and he lands on the skids. Eugene M. Emme, ed., **Aeronautics and Astronautics 1915-60**, p. 15.

1 **Aug. 22** The large Vickers Victoria military transport completes its first flight. It is designed to carry 25 soldiers in full combat gear a maximum of 640 kilometers at a speed of 160 kph. David Baker, **Flight and Flying: A Chronology**, p. 144.

1947

Aug. 7-10 William Odom makes an around-the-world solo flight in a converted Douglas A-26 Invader named the Reynolds Bombshell. He departed from Chicago and flew to Paris, then flew to Cairo, Tokyo, Karachi, Calcutta, Alaska and back to Chicago. **The Aeroplane**, Aug. 15, 1947, p. 177.

Aug. 9 The first jet fighter designed and built in South America makes its inaugural flight. Built in Argentina, the Pulqui (Arrow) is powered by a Rolls-Royce Derwent turbojet engine. **The Aeroplane**, Aug. 22, 1947, p. 208.

2 **Aug. 20** U.S. Navy Cmdr. Turner Caldwell pilots a Douglas D-558-1 Skystreak research aircraft to a new world speed record of 1,031 kph at Muroc, California. Five days later, U.S. Marine Corps Maj. Marion Carl beats the record by about 16 kph, flying a different D-558-1. E. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 57; F.K. Mason and M. Windrow, **Know Aviation**, p. 53.

3 **Aug. 22** NASA's predecessor the National Advisory Committee for Aeronautics appoints Hugh Dryden director of aeronautical research, replacing George Lewis. E. Emme., ed., **Aeronautics and Astronautics, 1915-60**, p. 58.

1972

Aug. 2 The most intense solar storm in two years, first observed by NASA's Orbiting Solar Observatory 7 in July, produces three major explosions. Ground stations and numerous other spacecraft are also observing the storm, including NASA's Explorer 41, 43 and 45. **NASA Release** 72-164.

4 **Aug. 3** A prototype of the U.S. Air Force's F-15 Eagle fighter aircraft completes its first supersonic flight, reaching Mach 1.5 during a 45-minute flight test at Edwards Air Force Base in California. The flight test program will end in March 1973, when the decision is made to have McDonnell Douglas manufacture the first 30 of 729 aircraft. NASA, **Aeronautics and Astronautics, 1972**, p. 282.

Aug. 3 Wearing pressurized spacesuits, astronauts Charles Conrad Jr., Paul Weitz and Joseph Kerwin enter a Skylab airlock module and multiple docking adapter inside a vacuum chamber at McDonnell Douglas Astronautics Co.'s St. Louis facility. This is among many checkouts the crew will conduct ahead of the first Skylab mission. **NASA Manned Spaceflight Center Release** 72-176.

Aug. 3 The U.S. Senate votes 88 to 2 to ratify the U.S.-Soviet Union treaty on the limitation of antiballistic missile systems. This treaty is formally ratified Aug 23. NASA, **Aeronautics and Astronautics, 1972**, pp. 283, 299.

Aug. 3 NASA announces the selection of 106 principal investigators, including 83 scientists from the U.S. and 23 from other nations, for Skylab Earth observation experiments. The investigators are to use data from Skylab's Earth resources experiment package consisting of five sensors developed to observe Earth simultaneously in visible, infrared and microwave spectral regions. **NASA Release** 72-150.

5 **Aug. 11** NASA's M2-F3 lifting body plane completes its 15th flight from the Flight Research Center at Edwards Air Force Base in California, piloted by the agency's William Dana. The objective of investigating stability and control at Mach 0.95 is achieved. NASA, **Aeronautics and Astronautics, 1972**, p. 289.

Aug. 13 A four-stage Scout rocket launches NASA's Explorer 46 satellite from NASA's Wallops in Virginia. Later designated the Micrometeoroid Technology Satellite, the spacecraft will evaluate the effectiveness of a bumper-protected multisheet spacecraft structure at guarding against micrometeoroid penetration. NASA, **Aeronautics and Astronautics, 1972**, p. 290

Aug. 17 RCA Global Communications Inc. signs a $5.7 million contract with the People's Republic of China to install a satellite Earth station outside Beijing and enlarge existing Earth stations near Shanghai. **Washington Post**, Aug. 18, 1972, p. D8.

Aug. 19 Japan launches its Denpa radio explorer satellite from the Kagoshima Space Center. The 75-kilogram satellite, the fourth spacecraft launched by Japan, is fitted with ionospheric plasma probes, electromagnetic and plasma-wave receivers, a cyclotron instability experiment, an electron flux analyzer and fluxgate magnetometer. NASA, **Aeronautics and Astronautics, 1972**, p. 295.

Aug. 21 An Atlas-Centaur rocket launches NASA's Orbiting Astronomical Observatory 3 satellite from Cape Kennedy in Florida. The satellite, renamed Copernicus after launch, will investigate the composition, density and physical state of matter in interstellar space and stellar sources. The secondary objective is to evaluate an onboard computer, light baffle star tracker and other equipment. **NASA Release** 72-156.

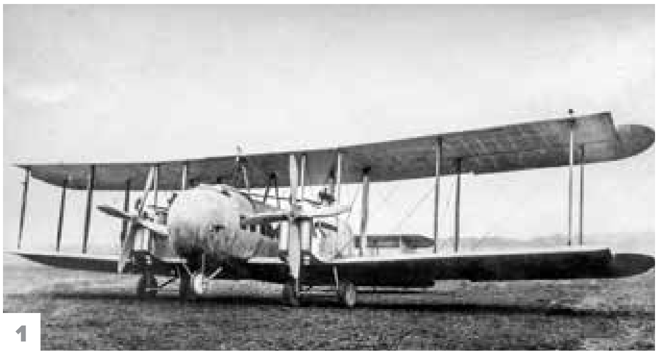
6 **Aug. 21** NASA announces that Apollo program director Rocco Petrone will take on the additional responsibility of program director of the Apollo Soyuz Test Project. Petrone will oversee the direction and management of the U.S. portion of the joint orbit mission with the Soviet Union, scheduled for 1975. **NASA Release** 72-174.

Aug. 21 The first pre-production Concorde supersonic transport aircraft completes its first stage of performance and handling characteristics tests, including 80 flights. The plane is then grounded for about 20 weeks for the installation of Rolls-Royce/Snecma Olympus engines and special intakes. **Aviation Week**, Aug. 2, 1972, p. 22.

Aug. 22 The Saturn IB that will launch Skylab 2 arrives at NASA's Kennedy Space Center on the barge Orion. The Saturn IB will launch the command and service modules in 1973 a day after the station's workshop is launched. **Kennedy Space Center Release** 246-72.

1997

Aug. 1 A Pegasus rocket launches the OrbView-2 satellite built by Orbital Imaging Corp. of Virginia to provide continuous monitoring of



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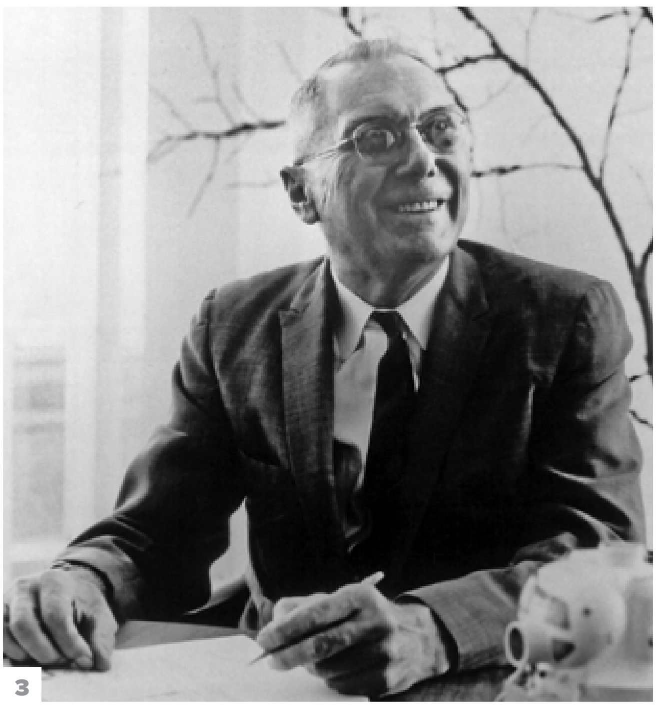

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the world's oceans. The satellite monitors severe weather, including El Niño phenomena, and provides data on microscopic toxic outbreaks in the oceans that kill millions of fish and affect human food supplies. **Aviation Week**, Oct. 20, 1997, p. 83.

Aug. 7 Space shuttle Discovery launches flight STS-85. Commanded by Curtis Brown Jr., the flight will test a new robotic arm and deploy a 3,200-kilogram German satellite to study the ozone layer. NASA, **Astronautics and Aeronautics: A Chronology, 1996-2000**, p. 86.

Aug. 20 China conducts the first successful launch of its Long March 3B rocket, sending the Mabuhay Philippines Satellite Corp.'s Agila 2 communications satellite to orbit. Agila 2, better known as Mabuhay 1, is the first Filipino communications satellite and Asia-Pacific's most powerful. **Aviation Week**, Aug. 25, 1997, p. 16.

The best technological surprise is none at all

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U.S. defense officials have known for years that China was testing prototypes of hypersonic missiles capable of taking out U.S. carrier groups, among other potential targets, but a test last July in which such a missile reportedly orbited Earth before entering the atmosphere and gliding to its target still elicited shock and concern.

For the United States, China's hypersonic test was a textbook example of technological surprise. That's when a competitor or adversary deploys a revolutionary new technology or an existing one in ways that were not anticipated.

One response to such a surprise, and it's the one the United States chose, would be turning the tables on an adversary by pouring funds into classified research and development in hopes of deterring the adversary. There's nothing wrong with increasing R&D when you fear you are behind, but those steps alone won't add up to deterring China or averting more surprises. Another part of the response should be a concerted effort to diagnose why the United States is so susceptible to being surprised by China. Understanding that could prevent us from being technologically surprised by other players on the world stage.

At its root, America, right now, has a collective penchant for confirmation bias — especially about China. When I chat with friends, colleagues and the general public regarding Chinese scientific and technological capabilities, most seem dismissive. After all, we are America, the world's leader in science and technology. This naive perspective is confirmed by some media portrayals of China as a country that only overcomes hurdles by spying on us and stealing our technology.

When it comes to China, such biases and portrayals could not be farther from the truth. When

CONTINUED ON PAGE 59

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